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(54) **POSITION ESTIMATION DEVICE, POSITION ESTIMATION METHOD, AND COMPUTER PROGRAM**

VORRICHTUNG ZUR POSITIONSSCHÄTZUNG, VERFAHREN ZUR POSITIONSSCHÄTZUNG UND COMPUTERPROGRAMM

DISPOSITIF D'ESTIMATION DE POSITION, PROCÉDÉ D'ESTIMATION DE POSITION ET PROGRAMME INFORMATIQUE

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EP 3 792 874 B1

Description

FIELD

[0001] Embodiments described herein relate generally to a position estimation device, , a position estimation method, and a computer program.

BACKGROUND

[0002] A position estimation device configured to estimate the self-position of an image capturing device has been known. The position estimation device estimates the self-position by using an image captured by the image capturing device and an observation value observed by a sensor attached to the image capturing device. The position estimation device sometimes estimates the self-position by using a state amount representing the state of the sensor in addition to the observation value observed by the sensor. For example, the state amount of an angular velocity sensor is a bias included in the angular velocity. The state amount of an acceleration sensor includes a bias included in the acceleration, the gravitational acceleration, and the speed.

[0003] The position estimation device estimates the state amount of a sensor based on the observation value observed by the sensor. However, the accuracy of the estimated state amount changes depending on a trajectory of the sensor and the like. For example, when constant speed linear motion is performed, the observation value of an acceleration sensor is substantially constant. Thus, the accuracies of the acceleration bias, the gravitational acceleration, and the speed decreases in such a case. The accuracy of the self-position estimation degrades when the position estimation device uses such a state amount having low accuracy.

[0004] US 2019 0273909 A1 relates to a method for obtaining a spatial configuration of a plurality of imaging devices relative to one another. The imaging devices are coupled to the movable object and comprise a first imaging device configured to operate in a multi-ocular mode and a second imaging device configured to operate in a monocular mode. The method further determining at least one of a distance of the movable object to an object or surface lying within a field-of-view of at least one of the imaging devices, a disparity between matched points in stereoscopic images acquired by the first imaging device, or an environment in which the plurality of imaging devices are operated. The distance is determined based in part on the spatial configuration.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005]

FIG. 1 is a diagram illustrating a moving object according to an embodiment;
FIG. 2 is a configuration diagram of a moving-object control system;
FIG. 3 is a configuration diagram of a position estimation device;
FIG. 4 is a flowchart illustrating the process of processing at the position estimation device;
FIG. 5 is a flowchart illustrating a process at a self-position estimation unit;
FIG. 6 is a flowchart illustrating the process of estimation processing in a first scheme;
FIG. 7 is a flowchart illustrating the process of estimation processing in a second scheme;
FIG. 8 is a flowchart illustrating the process of estimation processing in a third scheme; and
FIG. 9 is a configuration diagram of the position estimation device according to a modification.

DETAILED DESCRIPTION

[0006] The object of the invention is achieved by the subject-matter of the independent claims. Advantageous embodiments are defined in the dependent claims. Further examples are provided for facilitating the understanding of the invention.

[0007] A position estimation device according to the present disclosure is provided for estimating a self-position of a moving object device provided with one or more sensors. The position estimation device includes a state-amount estimation unit, a confidence-degree calculation unit, and a self-position estimation unit. The state-amount estimation unit is configured to estimate a state amount representing a state of each of the one or more sensors based on an observation value of the corresponding sensor. The confidence-degree calculation unit is configured to calculate a confidence degree representing a degree of confidence of the state amount of each of the one or more sensors. The self-position estimation unit is configured to: select one or more target sensors from among the one or more sensors based on the confidence degree of the state amount of each of the one or more sensors; and estimate the self-position based on the observation value and the state amount of each of the selected one or more target sensors.

[0008] The following describes an embodiment of the present invention with reference to the accompanying drawings.

[0009] FIG. 1 is a diagram illustrating a moving object device 10 according to an embodiment. In the present embodiment, the moving object device 10 is a vehicle such as an automobile or a motorcycle. However, the moving object device 10 is not limited to a vehicle but may be any device that can move by itself or is portable by a person, a robot, or the like. For example, the moving object device 10 may be a robot, a ship, or a flying object such as a drone.

[0010] A moving-object control system 12 is mounted on the moving object device 10. The moving-object control system 12 is, for example, a device including a dedicated or general-purpose computer. An information processing function of the moving-object control system 12 may not be mounted on the moving object device 10 but may be mounted on a device such as a cloud connected with the moving object device 10 through a network.

[0011] FIG. 2 is a diagram illustrating an exemplary configuration of the moving-object control system 12 according to the embodiment. The moving-object control system 12 includes an image capturing device 21, one or more sensors 22, a storage device 23, an input device 24, a display device 25, a communication device 26, a moving-object control device 27, and an information processing apparatus 40.

[0012] The image capturing device 21 is attached to the moving object device 10. In a fixed pose at a fixed position on the moving object device 10, the image capturing device 21 captures an image of vicinity of the moving object device 10. The pose of the image capturing device 21 does not need to be fixed as long as its pose relative to the moving object device 10 can be measured. In the present embodiment, the image capturing device 21 is a monocular camera. The image capturing device 21 may be a stereo camera or a depth camera. Alternatively, the image capturing device 21 may be a camera having a predetermined field of view or an omnidirectional camera. The image capturing device 21 generates a captured image through image capturing of vicinity of the moving object device 10 at each predetermined time interval.

[0013] The one or more sensors 22 are attached to the moving object device 10. Each of the one or more sensors 22 is attached, for example, in a fixed pose to a fixed position on the moving object device 10. Each of the one or more sensors 22 observes information related to movement of the moving object device 10.

[0014] In the present embodiment, the sensors 22 include an angular velocity sensor 31 and an acceleration sensor 32.

[0015] The angular velocity sensor 31 detects the angular velocity of the moving object device 10 as an observation value. The angular velocity sensor 31 detects an X-directional component, a Y-directional component, and a Z-directional component of the angular velocity. The X-directional component, the Y-directional component, and the Z-directional component are orthogonal to each other.

[0016] The acceleration sensor 32 detects the acceleration of the moving object device 10 as an observation value. The acceleration sensor 32 detects an X-directional component, a Y-directional component, and a Z-directional component of the acceleration.

[0017] The one or more sensors 22 may include a sensor other than the angular velocity sensor 31 and the acceleration sensor 32. For example, the one or more sensors 22 may include a speed sensor configured to detect the speed of the moving object device 10, and a position sensor configured to detect the position of the moving object device 10 based on signals from satellites or the like. In addition, the one or more sensors 22 may include a distance sensor, such as a LiDAR, configured to measure the distance to an object around the moving object device 10, sonar configured to detect an object around the moving object device 10 with sound wave, a geomagnetic sensor, or the like.

[0018] The storage device 23 is, for example, a semiconductor memory element such as a hard disk drive, an optical disk drive, or a flash memory. The storage device 23 stores computer programs executed by the moving-object control system 12 and data used by the moving-object control system 12.

[0019] The input device 24 receives instruction and information input by a user. The input device 24 is, for example, a pointing device such as an operation panel, a mouse, or a trackball, or an input device such as a keyboard.

[0020] The display device 25 displays various kinds of information to the user. The display device 25 is, for example, a display device such as a liquid crystal display device. The communication device 26 transmits and receives information to and from an external device through wireless communication.

[0021] The moving-object control device 27 controls a drive mechanism for moving the moving object device 10. For example, when the moving object device 10 is an automated driving vehicle, the moving-object control device 27 determines the status of the vicinity based on information obtained from the information processing apparatus 40 and other information, and controls an acceleration amount, a brake amount, a steering angle, and the like.

[0022] The information processing apparatus 40 is, for example, one or more dedicated or general-purpose computers. The information processing apparatus 40 manages and controls the image capturing device 21, the one or more sensors 22, the storage device 23, the input device 24, the display device 25, the communication device 26, and the moving-object control device 27. The information processing apparatus 40 includes a memory 41 and one or more hardware processors 42.

[0023] The memory 41 includes, for example, a read only memory (ROM 43) and a random access memory (RAM 44). The ROM 43 stores computer programs, various kinds of setting information, and the like used for control of the information processing apparatus 40 in a non-rewritable manner. The RAM 44 is a transitory storage medium such as a synchronous dynamic random access memory (SDRAM). The RAM 44 functions as a work area of the one or more hardware processors

42.

[0024] The one or more hardware processors 42 are connected with the memory 41 (the ROM 43 and the RAM 44) over a bus. For example, the one or more hardware processors 42 may include one or more central processing units (CPUs), and may include one or more graphics processing units (GPUs). In addition, the one or more hardware processors 42 may include, for example, a semiconductor device including a dedicated processing circuit for achieving a neural network.

[0025] The one or more hardware processors 42 function as a position estimation device 50 by executing various kinds of processing through cooperation with various computer programs stored in the ROM 43 or the storage device 23 in advance by using the RAM 44 as the work area. The position estimation device 50 will be described below in detail.

[0026] FIG. 3 is a diagram illustrating the configuration of the position estimation device 50. The position estimation device 50 estimates the self-position of the moving object device 10. More specifically, the moving object device 10 estimates a translation component of the self-position and a rotation component of the self-position.

[0027] The translation component of the self-position represents the coordinates (X-directional position, Y-directional position, and Z-directional position) of the moving object device 10 in the three-dimensional space. For example, the translation component of the self-position represents distances (X-directional distance, Y-directional distance, and Z-directional distance) from an optional reference point. The optional reference point may be, for example, the translation component of the self-position of the moving object device 10 at a predetermined time such as a start time.

[0028] The rotation component of the self-position represents the pose (rotation angle about an X axis, rotation angle about a Y axis, and rotation angle about a Z axis) of the moving object device 10. The rotation component may be an angle difference from an optional reference rotation angle. The optional reference rotation angle may be, for example, the rotation component of the self-position of the moving object device 10 at a predetermined time such as a start time. The rotation component may be expressed by, for example, a rotation matrix, a vector representing a rotational axis and a rotational direction, or a quaternion.

[0029] The position estimation device 50 estimates the self-position at each predetermined time interval. A time at which the self-position is to be estimated is referred to as a target time. A time before the target time, at which the self-position has already been estimated is referred to as a past time.

[0030] The position estimation device 50 includes a self-position storage unit 52, an image acquisition unit 54, an image storage unit 56, an observation-value acquisition unit 58, a state-amount estimation unit 60, a confidence-degree calculation unit 62, and a self-position estimation unit 64.

[0031] The self-position storage unit 52 stores the self-position at each of one or more past times. The image acquisition unit 54 acquires captured images captured by the image capturing device 21 at the target time. The image storage unit 56 stores captured images captured by the image capturing device 21 at one or more past times.

[0032] The observation-value acquisition unit 58 acquires an observation value observed by each of the one or more sensors 22. The observation-value acquisition unit 58 acquires the observation value, for example, in a temporally sequential manner. In the present embodiment, the observation-value acquisition unit 58 acquires the angular velocity observed by the angular velocity sensor 31 and the acceleration observed by the acceleration sensor 32 as observation values.

[0033] The state-amount estimation unit 60 estimates a state amount representing the state of each of the one or more sensors 22. In the present embodiment, the state-amount estimation unit 60 estimates, as the state amount representing the state of the angular velocity sensor 31, an angular velocity bias representing the bias of the angular velocity sensor 31. More specifically, the state-amount estimation unit 60 estimates an X-directional component, a Y-directional component, and a Z-directional component of the angular velocity bias.

[0034] In addition, in the present embodiment, the state-amount estimation unit 60 estimates, as the state amount representing the state of the acceleration sensor 32, the speed of the moving object device 10 in the translation direction, the gravitational acceleration, and an acceleration bias representing the bias of the acceleration sensor 32. More specifically, the state-amount estimation unit 60 estimates an X-directional component, a Y-directional component, and a Z-directional component of each of the speed, the gravitational acceleration, and the acceleration bias.

[0035] The state-amount estimation unit 60 may also estimate, as the state amount of the angular velocity sensor 31, for example, a positional difference amount between the image capturing device 21 and the angular velocity sensor 31 and a time stamp difference between the image capturing device 21 and the angular velocity sensor 31. The state-amount estimation unit 60 may also estimate, as the state amount of the acceleration sensor 32, for example, a position difference amount between the image capturing device 21 and the acceleration sensor 32 and a time stamp difference between the image capturing device 21 and the acceleration sensor 32. The state-amount estimation unit 60 may also estimate, as the state amount of each of the one or more sensors 22, a position difference amount between the sensor 22 and the image capturing device 21, a positional difference amount between the sensor 22 and a particular sensor 22, a time stamp difference between the sensor 22 and the image capturing device 21, and a time stamp difference between the sensor 22 and a particular sensor 22.

[0036] The position estimation device 50 can reduce degradation of the accuracy of the self-position estimation, which occurs due to change of the position of the sensor 22, by estimating, as the state amount of the sensor 22, the position difference amount between the sensor 22 and the image capturing device 21 or the positional difference amount between the sensor 22 and a particular sensor 22. The position estimation device 50 can also reduce degradation of the accuracy of the self-position estimation, which occurs due to variation of the time stamp of the sensor 22, by estimating, as the state amount of the sensor 22, the time stamp difference between the sensor 22 and the image capturing device 21 or the time stamp difference between the sensor 22 and a particular sensor 22.

[0037] The position estimation device 50 may estimate, as the state amount, a ratio of the translation component of the self-position estimated at a past time and the magnitude in the real world. Thereby, the position estimation device 50 can reduce degradation of the accuracy of the self-position estimation, which occurs due to deviation of the magnitude of the translation component of the self-position from the magnitude in the real world.

[0038] For example, for each of the one or more sensors 22, the state-amount estimation unit 60 estimates the state amount with which the residual error of a predetermined relational expression is minimized, the residual error being obtained when the self-position at each of one or more past times is substituted into the predetermined relational expression. The predetermined relational expression is an equation for calculating the self-position at the target time based on the self-position, the observation value of the corresponding sensor 22, and the state amount of the corresponding sensor 22 at the past time, and the time difference between the past time and the target time. For example, the predetermined relational expression is a motion equation for calculating the self-position at the target time based on the self-position at the past time.

[0039] The state-amount estimation unit 60 estimates, by, for example, a non-linear least-square method, the state amount with which the residual error of the predetermined relational expression is minimized. When the state amount changes in time, the state-amount estimation unit 60 estimates the state amount with which the residual error is minimized by repeatedly substituting the self-position at each of a plurality of past times into the predetermined relational expression by using, for example, a Levenberg-Marquardt method, a Gauss-Newton method, or a conjugate gradient method. When repeatedly substituting the self-position at each of a plurality of past times into the predetermined relational expression, the state-amount estimation unit 60 may unify the magnitude of the residual error by changing a weight for each past time. An exemplary method of estimating the state amounts of the angular velocity sensor 31 and the acceleration sensor 32 will be further described later with reference to FIG. 4.

[0040] The confidence-degree calculation unit 62 calculates a confidence degree representing the confidence of the state amount of each of the one or more sensors 22. When the value of the confidence degree is large, the degree of reliance and accuracy of the estimated state amount are high. When the value is small, the degree of reliance and accuracy of the estimated state amount are low.

[0041] For example, the confidence-degree calculation unit 62 calculates, as the confidence degree of the state amount, reciprocal of an expectation value of error of the state amount. The expectation value of error of the state amount can be obtained through, for example, calculation for minimizing the residual error when the state-amount estimation unit 60 estimates the state amount.

[0042] When the residual error is minimized by, for example, the non-linear least-square method, the state-amount estimation unit 60 estimates a covariance matrix of the state amount. For example, the state-amount estimation unit 60 estimates a covariance matrix of the X-directional component, the Y-directional component, and the Z-directional component of the state amount. In this case, the confidence-degree calculation unit 62 acquires the covariance matrix of the state amount from the state-amount estimation unit 60. Then, the confidence-degree calculation unit 62 calculates, as the confidence degree, the reciprocal of the sum of diagonal components of the acquired covariance matrix. When the sum of diagonal components of the covariance matrix is small, the error of the state amount is expected to be small and the accuracy thereof is high. When the sum is large, the error of the state amount is expected to be large and the accuracy thereof is low.

[0043] The moving object device 10 may include a second sensor configured to observe an observation value corresponding to the state amount. In this case, the confidence-degree calculation unit 62 may calculate the confidence degree by comparing the observation value of the second sensor and the estimated state amount. For example, in a case in which the speed is estimated as the state amount and the moving object device 10 includes a speed meter configured to check the speed based on the rotation speed of a wheel, the confidence-degree calculation unit 62 calculates the confidence degree to be high when the observation value of the speed meter and the estimated speed are close to each other, or calculates the confidence degree to be low when the observation value and the estimated speed are far from each other.

[0044] When a possible range of the state amount is predicted, the confidence-degree calculation unit 62 may calculate, as the confidence degree, the degree of match of the estimated state amount with a value or range set in advance. For example, possible ranges of the angular velocity bias of the angular velocity sensor 31 and the acceleration bias of the acceleration sensor 32 can be predicted by evaluating characteristics thereof or the like in advance. Thus, the confidence-degree calculation unit 62 may calculate, as the confidence degree, the degrees of match of the estimated angular velocity bias and the estimated acceleration bias with the predicted ranges. The direction of the gravitational acceleration can be predicted based on attachment pose of the acceleration sensor 32 relative to the ground. Thus, the confidence-degree calculation unit 62 may calculate, as the confidence degree, the degree of match of an estimated direction of the gravitational acceleration with the predicted direction of the gravitational acceleration.

[0045] The self-position estimation unit 64 selects one or more target sensors from among the one or more sensors 22 based on the confidence degree of the state amount of each of the one or more sensors 22. For example, the self-position estimation unit 64 selects, as target sensors from among the one or more sensors 22, one or more sensors 22 whose confidence degrees of the state amounts are equal to or higher than a predetermined threshold. Then, the self-position estimation unit 64 estimates the self-position based on the observation value and the state amount of each of the one or more selected target sensors.

[0046] For example, the self-position estimation unit 64 estimates the self-position at the target time based on: a captured image captured by the image capturing device 21 at the target time; a captured image at a past time; the self-position at the past time; and the observation value and the state amount of each of the one or more selected target sensors. When the one or more sensors 22 include none of the one or more target sensors whose confidence degrees of the state amounts are equal to or higher than the threshold, the self-position estimation unit 64 may estimate the self-position without using the observation value and the state amount of the sensors 22. Specifically, in this case, the self-position estimation unit 64 estimates the self-position at the target time based on the captured image at the target time, the captured image at the past time, and the self-position at the past time. The estimation processing performed by the self-position estimation unit 64 will be described in more detail with reference to FIG. 5 and the subsequent drawings.

[0047] Then, the self-position estimation unit 64 outputs the estimated self-position at the target time. For example, the self-position estimation unit 64 outputs the estimated self-position at the target time to the moving-object control device 27. The moving-object control device 27 acquires the self-position estimated at each predetermined time interval. The moving-object control device 27 controls movement of the moving object device 10 based on the estimated self-position.

[0048] FIG. 4 is a flowchart illustrating the process of processing at the position estimation device 50. The position estimation device 50 estimates the self-position at the target time by executing the processing illustrated in FIG. 4 at each predetermined time interval.

[0049] Firstly, at S11, the image acquisition unit 54 acquires the captured image at the target time. Subsequently, at S12, the observation-value acquisition unit 58 acquires the observation value observed by each of the one or more sensors 22. For example, the observation-value acquisition unit 58 acquires the observation value measured in synchronization with the image-capturing timing of the captured image at the target time.

[0050] Subsequently, at S13, the state-amount estimation unit 60 estimates the state amount representing the state of each of the one or more sensors 22. In the present embodiment, the state-amount estimation unit 60 estimates, as the state amount representing the state of the angular velocity sensor 31, the angular velocity bias representing the bias of the angular velocity sensor 31.

[0051] For example, the state-amount estimation unit 60 estimates the angular velocity bias with which a residual error (first residual error) is minimized. The residual error is obtained when the rotation component of the self-position at the past time is substituted into a rotation-component motion equation. The rotation-component motion equation is a relational expression for calculating the rotation component of the self-position at the target time based on the rotation component of the self-position at the past time.

[0052] Specifically, the rotation-component motion equation is expressed by Expression (1) below:

$$R(t+\Delta t) = R(t)\times \mathrm{Exp}((\omega(t) - b_g)\Delta t) \qquad (1)$$

[0053] In the expression, "Exp" represents the exponential map of the 3D rotation group, which converts the value of the angular velocity to the rotation component. In Expression (1), "x" represents composition of a plurality of rotation components.

[0054] In the expression, $R(t+\Delta t)$ represents the rotation component of the self-position at the target time, $R(t)$ represents the rotation component of the self-position at the past time, $\omega(t)$ represents the measured angular velocity, b_g represents the angular velocity bias as an estimation target, and Δt represents the time difference between the past time and the target time. The first residual error can be calculated as, for example, the magnitude of the rotation angle of a rotation component obtained by synthesizing inverse rotation of the rotation component on the left-hand side of Expression (1) with the rotation component on the right-hand side of Expression (1).

[0055] The state-amount estimation unit 60 may substitute the rotation component of the self-position at each of a plurality of past times into the rotation-component motion equation of Expression (1) and estimate the angular velocity bias by the non-linear least-square method. In this case, the state-amount estimation unit 60 estimates the angular velocity bias, with which the first residual error is minimized, by repeatedly substituting the self-position at each of the plurality of past times into the rotation-component motion equation by using, for example, the Levenberg-Marquardt method, the Gauss-Newton method, or the conjugate gradient method. Thereby, the state-amount estimation unit 60 estimates the angular velocity bias that changes in time.

[0056] In addition, in the present embodiment, the state-amount estimation unit 60 estimates, as the state amount representing the state of the acceleration sensor 32, the speed of the moving object device 10 in the translation direction, the gravitational acceleration, and the acceleration bias representing the bias of the acceleration sensor 32.

[0057] For example, the state-amount estimation unit 60 estimates the speed in the translation direction, the gravitational acceleration, and the acceleration bias with which a residual error (second residual error) is minimized, the residual error being obtained when the translation component of the self-position at the past time is substituted into a translation-component motion equation. The translation-component motion equation is a relational expression for calculating the translation component of the self-position at the target time based on the translation component of the self-position at the past time.

[0058] Specifically, the translation-component motion equation is expressed by Expressions (2) and (3) below:

$$p(t+\Delta t) = p(t) + v(t)\times\Delta t + (1/2)\times g\times\Delta t^2 + (1/2)\times R(t)\times(a(t) - b_a)\times\Delta t^2 \qquad (2)$$

$$v(t+\Delta t) = v(t) + g\times\Delta t + R(t)\times(a(t) - b_a)\times\Delta t \qquad (3)$$

[0059] In the expression, $p(t+\Delta t)$ represents the translation component of the self-position at the target time, $p(t)$ represents the translation component of the self-position at the past time, $v(t)$ represents the speed as an estimation target, Δt represents the time difference between the past time and the target time, g represents the gravitational acceleration as an estimation target, b_a represents the acceleration bias as an estimation target, and $v(t+\Delta t)$ represents the speed at the target time. The second residual error can be calculated as, for example, a weighted sum of the magnitude of a vector obtained by subtracting the right-hand side of Expression (2) from the left-hand side of Expression (2) and the magnitude of a vector obtained by subtracting the right-hand side of Expression (3) from the left-hand side of Expression (3).

[0060] The state-amount estimation unit 60 may substitute the translation component of the self-position at each of a plurality of past times into the translation-component motion equation of Expressions (2) and (3) and estimate the speed, the gravitational acceleration, and the acceleration bias by the non-linear least-square method. In this case, the state-amount estimation unit 60 estimates the speed, the gravitational acceleration, and the acceleration bias with which the second residual error is minimized by repeatedly substituting the self-position at each of a plurality of past times into the translation-component motion equation by using, for example, the Levenberg-Marquardt method, the Gauss-Newton method, or the conjugate gradient method. Thereby, the state-amount estimation unit 60 estimates the speed, the gravitational acceleration, and the acceleration bias that change in time.

[0061] Subsequently, at S14, the confidence-degree calculation unit 62 calculates the confidence degree of the state amount of each of the one or more sensors 22.

[0062] The confidence-degree calculation unit 62 acquires a covariance matrix of the X-directional component, the Y-directional component, and the Z-directional component of the estimated angular velocity bias, which are orthogonal to each other. For example, the confidence-degree calculation unit 62 acquires the covariance matrix of the angular velocity bias, which is calculated by the state-amount estimation unit 60 in the process of calculation of the angular velocity bias by using the non-linear least-square method at S13. Then, the confidence-degree calculation unit 62 calculates, as the confidence degree of the angular velocity bias, the reciprocal of the sum of diagonal components of the acquired covariance matrix of the angular velocity bias.

[0063] In addition, the confidence-degree calculation unit 62 acquires a covariance matrix of the X-directional component, the Y-directional component, and the Z-directional component of the estimated acceleration bias, which are orthogonal to each other. For example, the confidence-degree calculation unit 62 acquires the covariance matrix of the acceleration bias, which is calculated by the state-amount estimation unit 60 in the process of calculation of the acceleration bias by using the non-linear least-square method at S13. Then, the confidence-degree calculation unit 62 calculates, as the confidence degree of the acceleration bias, the reciprocal of the sum of diagonal components of the acquired covariance matrix of the acceleration bias.

[0064] Subsequently, at S15, the self-position estimation unit 64 estimates the translation and rotation components of the self-position at the target time. The method of estimating the self-position at the target time will be described later with reference to FIGS. 5 and 6.

[0065] Subsequently, at S16, the self-position estimation unit 64 outputs the estimated self-position at the target time. For example, the self-position estimation unit 64 outputs the estimated self-position at the target time to the moving-object control device 27. In addition, the self-position estimation unit 64 stores the estimated self-position at the target time in the self-position storage unit 52 in association with time information.

[0066] The position estimation device 50 estimates the self-position at each predetermined time interval by repeatedly executing the above-described processing at S11 to S16 at each predetermined time interval.

[0067] FIG. 5 is a flowchart illustrating a process at the self-position estimation unit 64. In the present embodiment, the self-position estimation unit 64 executes processing through the process illustrated in FIG. 5.

[0068] Firstly, at S21, the self-position estimation unit 64 determines whether the confidence degree of the bias of the angular velocity is equal to or higher than a threshold set in advance. When the confidence degree of the angular velocity bias is not equal to or higher than the threshold (No at S21), the self-position estimation unit 64 advances the processing to S23. When the confidence degree of the angular velocity bias is equal to or higher than the threshold (Yes at S21), the self-position estimation unit 64 advances the processing to S22.

[0069] Subsequently, at S22, the self-position estimation unit 64 determines whether the confidence degree of the bias of the acceleration is equal to or higher than the threshold. When the confidence degree of the acceleration bias is not equal to or higher than the threshold (No at S22), the self-position estimation unit 64 advances the processing to S24. When the confidence degree of the acceleration bias is equal to or higher than the threshold (Yes at S22), the self-position estimation unit 64 advances the processing to S25.

[0070] At S23, the self-position estimation unit 64 estimates the self-position at the target time in a first scheme. Specifically, the self-position estimation unit 64 selects the first scheme when the confidence degree of the angular velocity bias is not equal to or higher than the threshold.

[0071] In the first scheme, the self-position estimation unit 64 estimates the self-position at the target time based on the captured image at the target time, the captured image at the past time, and the self-position at the past time. Thereby, the self-position estimation unit 64 estimates the self-position at the target time without using the observation value and state amount of each of the angular velocity sensor 31 and the acceleration sensor 32 when the confidence degree of the state amount of the angular velocity sensor 31 is not equal to or higher than the threshold.

[0072] More detailed processing contents of the first scheme will be described later with reference to FIG. 6. When the processing at S23 is completed, the self-position estimation unit 64 ends the processing of the present process.

[0073] At S24, the self-position estimation unit 64 estimates the self-position at the target time in a second scheme. Specifically, the self-position estimation unit 64 selects the second scheme when the confidence degree of the angular velocity bias is equal to or higher than the threshold but the confidence degree of the acceleration bias is not equal to or higher than the threshold.

[0074] In the second scheme, the self-position estimation unit 64 estimates the self-position at the target time based on the captured image at the target time, the measured angular velocity, the estimated angular velocity bias, the captured image at the past time, and the self-position at the past time. Thereby, the self-position estimation unit 64 selects, as a target sensor, the angular velocity sensor 31 whose confidence degree of the state amount is equal to or higher than the threshold, and estimates the self-position based on the observation value and the state amount of the selected angular velocity sensor 31.

[0075] More detailed processing contents of the second scheme will be described later with reference to FIG. 7. When the processing at S24 is completed, the self-position estimation unit 64 ends the processing of the present process.

[0076] At S25, the self-position estimation unit 64 estimates the self-position at the target time in a third scheme. Specifically, the self-position estimation unit 64 selects the third scheme, when the confidence degree of the angular velocity bias and the confidence degree of the acceleration bias are both equal to or higher than the threshold.

[0077] In the third scheme, the self-position estimation unit 64 estimates the self-position at the target time based on the captured image at the target time, the measured angular velocity, the estimated angular velocity bias, the measured acceleration, the estimated speed, the estimated gravitational acceleration, the estimated acceleration bias, the captured image at the past time, and the self-position at the past time. Thereby, the self-position estimation unit 64 selects, as target sensors, the angular velocity sensor 31 and the acceleration sensor 32 whose confidence degrees of the state amounts are equal to or higher than the threshold, and estimates the self-position based on the observation value and the state amount of each of the selected angular velocity sensor 31 and the selected acceleration sensor 32.

[0078] More detailed processing contents of the third scheme will be described later with reference to FIG. 8. When the processing at S25 is completed, the self-position estimation unit 64 ends the processing of the present process.

[0079] FIG. 6 is a flowchart illustrating the process of the estimation processing in the first scheme at S23. The self-position estimation unit 64 executes, at S23, the processing illustrated in FIG. 6.

[0080] Firstly, at S31, the self-position estimation unit 64 estimates the translation component of the self-position at the target time based on the translation component of the self-position at the past time. For example, the self-position estimation unit 64 estimates the translation component of the self-position at the target time through extrapolation processing by applying the translation component of the self-position at each of a plurality of past times to a constant speed linear motion model. The self-position estimation unit 64 may calculate the translation component of the self-position at the target time by applying the translation component of the self-position at each of a plurality of past times to another model in place of the constant speed linear motion model. The self-position estimation unit 64 may calculate the translation component of the self-position at the target time by fitting a curve, such as a spline curve, to the translation component of the self-position at each of a plurality of past times.

[0081] Subsequently, at S32, the self-position estimation unit 64 estimates the rotation component of the self-position at the target time based on the rotation component of the self-position at the past time. For example, the self-position estimation unit 64 estimates the rotation component of the self-position at the target time through extrapolation processing by applying the rotation component of the self-position at each of a plurality of past times to an constant angular velocity motion model. The self-position estimation unit 64 may calculate the rotation component of the self-position at the target time by applying the rotation component of the self-position at each of a plurality of past times to another model in place of the equiangular velocity motion model. The self-position estimation unit 64 may calculate the rotation component of the self-position at the target time by fitting a curve, such as a spline curve, to the rotation component of the self-position at each of a plurality of past times.

[0082] Subsequently, at S33, the self-position estimation unit 64 associates each of one or more feature points included in the captured image at the target time with the corresponding feature point included in the captured image at the past time.

[0083] The self-position estimation unit 64 calculates the three-dimensional position of the corresponding feature point included in the captured image at the past time by using, for example, structure-from-motion or simultaneous localization and mapping (SLAM). The self-position estimation unit 64 projects the calculated three-dimensional position onto the captured image at the target time from the self-position at the target time, which is estimated at S31 and S32, and specifies a candidate position on the captured image at the target time. The self-position estimation unit 64 searches for similar texture in vicinity of the candidate position on the captured image at the target time, and associates a feature point included in the captured image at the target time with the corresponding feature point included in the captured image at the past time.

[0084] In addition, the self-position estimation unit 64 calculates, as an epipolar line, a candidate position at which the feature point included in the captured image at the past time exists based on the position of the feature point included in the captured image at the target time and the self-position estimated at S31 and S32. Then, the self-position estimation unit 64 may search for similar texture near the epipolar line of the captured image at the past time, and associate the feature point included in the captured image at the target time with the corresponding feature point included in the captured image at the past time.

[0085] The self-position estimation unit 64 calculates the similarity of texture based on, for example, the luminance value difference between peripheral regions of pixels. The self-position estimation unit 64 may calculate the similarity of texture based on a local characteristic descriptor such as SIFT, SURF, ORB, or AKAZE. Alternatively, the self-position estimation unit 64 may produces in advance a neural network for determining whether two local regions correspond to each other, and may calculate the similarity by using the neural network.

[0086] With respect to each of captured images at a plurality of past times, the self-position estimation unit 64 may associate each of one or more feature points included in the captured image at the target time with the corresponding feature point included in the captured image at the past time.

[0087] Subsequently, at S34, the self-position estimation unit 64 adjusts the self-position at the target time estimated at S31 and S32 to minimize a reprojection error. The reprojection error is the evaluation value of an error between the pixel position of each of the one or more feature points included in the captured image at the target time and a pixel position at which the three-dimensional position of the corresponding feature point included in the captured image at the past time is reprojected onto the captured image at the target time based on the estimated self-position at the target time. For example, the self-position estimation unit 64 uses the non-linear least-square method or the like when adjusting the self-position at the target time to minimize the reprojection error.

[0088] Then, the self-position estimation unit 64 outputs the self-position at the target time adjusted at S34. After having completed S34, the self-position estimation unit 64 ends the present process.

[0089] FIG. 7 is a flowchart illustrating the process of the estimation processing in the second scheme at S24. The self-position estimation unit 64 executes, at S24, the processing illustrated in FIG. 7.

[0090] Firstly, at S41, the self-position estimation unit 64 estimates the translation component of the self-position at the target time based on the translation component of the self-position at the past time. For example, the self-position estimation unit 64 executes, at S41, processing the same as that at S31 in FIG. 6.

[0091] Subsequently, at S42, the self-position estimation unit 64 estimates the rotation component of the self-position at the target time based on the rotation component of the self-position at the past time, the measured angular velocity, and the estimated angular velocity bias. More specifically, the self-position estimation unit 64 calculates the rotation component of the self-position at the target time by substituting the rotation component of the self-position at the past time, the measured angular velocity, and the estimated angular velocity bias into the rotation-component motion equation in the foregoing Expression (1). At S42, in place of the above-described processing, the self-position estimation unit 64 may execute processing the same as that at S32 in FIG. 6.

[0092] Subsequently, at S43, the self-position estimation unit 64 associates each of the one or more feature points included in the captured image at the target time with the corresponding feature point included in the captured image at the past time. For example, the self-position estimation unit 64 executes, at S43, processing the same as that at S33 in FIG. 6.

[0093] Alternatively, at S43, the self-position estimation unit 64 may predict feature point rotation based on the rotation-component motion equation in the foregoing Expression (1), and may deform an image of a region around the feature point in the captured image at the past time in the rotational direction before calculating the similarity of texture. Thereby, the self-position estimation unit 64 can accurately execute the feature point association.

[0094] Subsequently, at S44, the self-position estimation unit 64 adjusts the self-position at the target time estimated at S41 and S42 to minimize the sum of the reprojection error and the first residual error in the rotation-component motion equation. The first residual error in the rotation-component motion equation is the evaluation value of the residual error obtained when the rotation component of the self-position at the past time, the measured angular velocity, and the estimated angular velocity bias are substituted into the rotation-component motion equation.

[0095] The self-position estimation unit 64 uses, for example, the non-linear least-square method or the like when adjusting the self-position at the target time to minimize the sum of the reprojection error and the first residual error. The reprojection error and the first residual error in the rotation-component motion equation have different units. Thus, the self-position estimation unit 64 may normalize each of the reprojection error and the first residual error before calculating the sum.

[0096] The self-position estimation unit 64 fixes the state amount (in this example, the angular velocity bias) when adjusting the self-position at the target time. Instead, the self-position estimation unit 64 may perform adjustment to minimize both the state amount and the self-position at the target time.

[0097] Then, the self-position estimation unit 64 outputs the self-position at the target time adjusted at S44. After having completed S44, the self-position estimation unit 64 ends the present process.

[0098] FIG. 8 is a flowchart illustrating the process of the estimation processing in the third scheme at S25. The self-position estimation unit 64 executes, at S25, the processing illustrated in FIG. 8.

[0099] Firstly, at S51, the self-position estimation unit 64 estimates the translation component of the self-position at the target time based on the translation component of the self-position at the past time, the measured acceleration, the estimated speed, the estimated gravitational acceleration, and the estimated acceleration bias. More specifically, the self-position estimation unit 64 calculates the translation component of the self-position at the target time by substituting the translation component of the self-position at the past time, the estimated speed, the estimated gravitational acceleration, and the estimated acceleration bias into the translation-component motion equation in Expressions (2) and (3). At S51, in place of the above-described processing, the self-position estimation unit 64 may execute processing the same as that at S31 in FIG. 6.

[0100] Subsequently, at S52, the self-position estimation unit 64 estimates the rotation component of the self-position at the target time based on the rotation component of the self-position at the past time, the measured angular velocity, and the estimated angular velocity bias. More specifically, the self-position estimation unit 64 calculates the rotation component of the self-position at the target time by substituting the rotation component of the self-position at the past time, the measured angular velocity, and the estimated angular velocity bias into the rotation-component motion equation in Expression (1). At S52, in place of the above-described processing, the self-position estimation unit 64 may execute processing the same as that at S32 in FIG. 6.

[0101] Subsequently, at S53, the self-position estimation unit 64 associates each of the one or more feature points included in the captured image at the target time with the corresponding feature point included in the captured image at the past time. For example, the self-position estimation unit 64 executes, at S53, processing the same as that at S33 in FIG. 6.

[0102] Alternatively, at S53, the self-position estimation unit 64 may deform, based on the direction of the estimated gravitational acceleration, the image of the region around the feature point in the captured image at the past time so that directions of the gravitational acceleration in the captured image at the target time and the captured image at the past time are aligned with each other, before calculating the similarity of texture. Thereby, the self-position estimation unit 64 can accurately execute the feature point association.

[0103] At S53, instead of the above processing, the self-position estimation unit 64 may predict feature point rotation based on the rotation-component motion equation in the foregoing Expression (1), and may deform the image of the region around the feature point in the captured image at the past time in the rotational direction before calculating the similarity of texture. In this manner as well, the self-position estimation unit 64 can accurately execute the feature point association.

[0104] Furthermore, at S53, the self-position estimation unit 64 may combine the alignment of the direction of the gravitational acceleration and the prediction of the feature point rotation, and may deform the image of the region around the feature point in the captured image at the past time in the rotational direction before calculating the similarity of texture.

[0105] Subsequently, at S54, the self-position estimation unit 64 adjusts the self-position at the target time estimated at S51 and S52 to minimize the sum of the reprojection error, the first residual error in the rotation-component motion equation, and the second residual error in the translation-component motion equation. The second residual error in the translation-component motion equation is the evaluation value of the residual error obtained when the translation component of the self-position at the past time, the measured acceleration, the estimated speed, the estimated gravitational acceleration, and the estimated acceleration bias are substituted into the translation-component motion equation.

[0106] The self-position estimation unit 64 uses, for example, the non-linear least-square method or the like when adjusting the self-position at the target time to minimize the sum of the reprojection error, the first residual error, and the second residual error. The reprojection error, the first residual error, and the second residual error have different units. Thus, the self-position estimation unit 64 may normalize each of the reprojection error, the first residual error, and the second residual error before calculating the sum.

[0107] The self-position estimation unit 64 fixes the state amounts (in this example, the angular velocity bias, the speed, the gravitational acceleration, and the angular velocity bias) when adjusting the self-position at the target time. Instead, the self-position estimation unit 64 may perform adjustment to minimize both any one or more the state amounts and the self-position at the target time.

[0108] Then, the self-position estimation unit 64 outputs the self-position at the target time adjusted at S54. After having completed S54, the self-position estimation unit 64 ends the present process.

[0109] The first scheme, the second scheme, and the third scheme described above each include the four pieces of processing of the estimation processing of the translation component of the self-position (S31, S41, and S51), the estimation processing of the rotation component of the self-position (S32, S42, and S52), the feature point association processing (S33, S43, and S53), and the self-position adjustment processing (S34, S44, and S54).

[0110] The self-position estimation unit 64 may share any of the four pieces of processing among the first scheme, the second scheme, and the third scheme, and switch the other pieces of processing in accordance with the confidence degree of the state amount. For example, the self-position estimation unit 64 may share the feature point association processing in the processing at S33, and switch the estimation processing of the translation component of the self-position, the estimation processing of the rotation component of the self-position, and the self-position adjustment processing in accordance with the confidence degree of the state amount.

[0111] FIG. 9 is a diagram illustrating the configuration of the position estimation device 50 according to a modification. In addition to the configuration illustrated in FIG. 3, the position estimation device 50 may further include a motion-kind specification unit 74, an anomaly determination unit 76, and a resetting unit 78.

[0112] The motion-kind specification unit 74 specifies a kind of motion of the moving object device 10 based on a trajectory of the estimated self-position. For example, the motion-kind specification unit 74 specifies whether the moving object device 10 is performing constant-speed linear motion, performing constant-acceleration linear motion, performing circular motion, or is stationary. For example, when the moving object device 10 is performing motion other than motion kinds set in advance, the motion-kind specification unit 74 may specify that the moving object device 10 is performing the other motion.

[0113] The motion-kind specification unit 74 specifies the motion kind by, for example, evaluating the residual error between the trajectory of the estimated self-position and each of a plurality of models described in advance. When the residual error between the trajectory of the self-position and any of the plurality of models is equal to or larger than a threshold, the motion-kind specification unit 74 specifies that the moving object device 10 is performing other motion. When the residual error from the trajectory of the self-position is smaller than the threshold for a plurality of models, the motion-kind specification unit 74 may specify a plurality of motion kinds. The motion-kind specification unit 74 may specify the motion kind by using a classification means such as a neural network.

[0114] The anomaly determination unit 76 acquires the motion kind specified by the motion-kind specification unit 74. In addition, the anomaly determination unit 76 acquires one or more target sensors selected by the self-position estimation unit 64 to estimate the self-position. In other words, the anomaly determination unit 76 acquires a combination of the sensors 22 whose estimated confidence degrees of the state amounts are relatively high. In the present embodiment, the anomaly determination unit 76 acquires which of the first scheme, the second scheme, and the third scheme is selected.

[0115] Subsequently, the anomaly determination unit 76 determines whether the combination of the one or more selected target sensors correspond to the specified motion kind, and determines that the operation is anomalous when no correspondence is obtained or that the operation is normal when the correspondence is obtained. In the present embodiment, the anomaly determination unit 76 determines whether the selected scheme corresponds to the specified motion kind, and determines that the operation is anomalous when no correspondence is obtained or that the operation is normal when the correspondence is obtained.

[0116] The anomaly determination unit 76 stores in advance an expected pattern of a selected scheme for each motion kind, for example. Then, when matching is made with the stored pattern, the anomaly determination unit 76 determines that the selected scheme corresponds to the specified motion kind.

[0117] Here, a situation is assumed, in which the motion kind is constant-speed linear motion. In this situation, since the acceleration is zero, it is difficult for the state-amount estimation unit 60 to estimate the speed. Thus, the selected scheme is expected to be the first scheme or the second scheme but not the third scheme that uses the acceleration, the angular velocity, and the captured image. In this situation, when the third scheme is selected, it is thought that anomaly is occurring in acquisition of the observation value of the sensor 22 or in calculation and the like for the self-position estimation.

[0118] Thus, in the case where the motion kind is constant-speed linear motion and the third scheme is selected, the anomaly determination unit 76 determines that the operation is anomalous. In contrast, the anomaly determination unit 76 determines that the operation is normal when the motion kind is constant-speed linear motion and either the first scheme or the second scheme is selected. The anomaly determination unit 76 may determine that the operation is normal when another motion kind is specified and any scheme is selected. When a plurality of motion kinds are specified, the anomaly determination unit 76 determines whether each of the plurality of specified motion kinds corresponds to the motion kind specified by the selected scheme, and integrates determination results of the plurality of specified motion kinds to determine whether the operation is anomalous.

[0119] When the anomaly determination unit 76 determines that the operation is anomalous, the resetting unit 78 resets the self-position at the past time so that the self-position estimation unit 64 newly estimates the self-position at the target time. For example, when the anomaly determination unit 76 determines that the operation is anomalous, the resetting unit 78 sets the current self-position as a reference point so that the self-position estimation unit 64 newly estimates the self-position at the target time. Thereby, the self-position estimation unit 64 can newly estimate the self-position by using the self-position at the past time when the operation is determined to be normal.

[0120] The position estimation device 50 according to the modification described above can evaluate the relation between the selected self-position estimation scheme and the estimated self-position. Then, the position estimation device 50 can perform self-diagnosis of whether the estimation operation at the position estimation device 50 is anomalous based on a result of the evaluation of the relation between the estimation scheme and the estimated self-position.

[0121] Furthermore, the position estimation device 50 according to the modification can newly estimate the self-position based on a result of the self-diagnosis. Accordingly, the self-position can be more accurately estimated by the position estimation device 50 according to the modification.

[0122] As described above, the position estimation device 50 according to the present embodiment estimates the state amount representing the state of each of the one or more sensors 22, and calculates the confidence degree of the state amount of each of the one or more sensors 22. Then, the position estimation device 50 selects one or more target sensors from among the one or more sensors 22 based on the confidence degree of the state amount of each of the one or more sensors 22, and estimates the self-position based on the observation value and the state amount of each of the one or more selected target sensors.

[0123] Therefore, the position estimation device 50 is capable of avoiding degradation of the accuracy of the self-position estimation due to use of the state amount whose confidence degree is relatively low. Thus, the position estimation device 50 can accurately estimate the self-position of the moving object device 10 by using the observation value and the state amount of each sensor 22 whose confidence degree of the state amount is relatively high.

[0124] While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms. The accompanying claims are intended to cover such forms or modifications as would fall within the scope of the invention.

Claims

1. A position estimation device (50) for estimating a self-position of a moving object device (10) provided with one or more sensors (22) for observing information related to movement and further provided with an image capturing device (21) capturing an image of vicinity of the moving object device (10); the self-position including a translation component and a rotation component; the one or more sensors including an angular velocity sensor (31) and an acceleration sensor (32), the angular velocity sensor measures the angular velocity of the moving object device (10) at the target time, and the acceleration sensor measures the acceleration of the moving object device (10) at the target time;
the position estimation device (50) comprising:

a state-amount estimation unit (60) configured to estimate a state amount representing a state of each of the one or more sensors (22) based on an observation value of the corresponding sensor;
a confidence-degree calculation unit (62) configured to calculate a confidence degree representing a degree of confidence of the state amount of each of the one or more sensors (22); and
a self-position estimation unit (64) configured to select one or more target sensors from among the one or more sensors (22) based on the confidence degree of the state amount of each of the one or more sensors, and to estimate the self-position based on the observation value and the state amount of each of the selected one or more target sensors;
wherein:

when the one or more sensors include one or more target sensors whose confidence degrees are equal to or higher than a predetermined threshold, the self-position estimation unit (64) selects, as the one or more target sensors from among the one or more sensors, one or more sensors whose confidence degrees of the state amounts are equal to or higher than the threshold;
the self-position estimation unit (64) estimates the self-position at a target time based on a captured image

captured by the image capturing device at the target time, the captured image at a past time before the target time, the self-position at the past time, and the observation value and the state amount of each of the selected one or more target sensors;

when the one or more sensors include none of the one or more sensors whose confidence degrees are equal to or higher than the threshold, the self-position estimation unit (64) estimates the self-position at the target time based on the captured image at the target time, the captured image at the past time, and the self-position at the past time;

wherein the state-amount estimation unit (60) estimates, as the state amount of the angular velocity sensor, an angular velocity bias of the moving object device, and estimates, as the state amount of the acceleration sensor, the speed and gravitational acceleration of the moving object device and an acceleration bias of the moving object device; and

wherein the self-position estimation unit (64) estimates the self-position at the target time based on a first scheme in which the self-position at the target time is estimated based on the captured image at the target time, the captured image at the past time, and the self-position at the past time,

a second scheme in which the self-position at the target time is estimated based on the captured image at the target time, the measured angular velocity, the estimated angular velocity bias, the captured image at the past time, and the self-position at the past time, or

a third scheme in which the self-position at the target time is estimated based on the captured image at the target time, the measured angular velocity, the estimated angular velocity bias, the measured acceleration, the estimated speed, the estimated gravitational acceleration, the estimated acceleration bias, the captured image at the past time, and the self-position at the past time, and

selects the first scheme when the confidence degree of the angular velocity bias is not equal to or higher than the threshold,

selects the second scheme when the confidence degree of the angular velocity bias is equal to or higher than the threshold and the confidence degree of the acceleration bias is not equal to or higher than the threshold, and

selects the third scheme when the confidence degree of the angular velocity bias and the confidence degree of the acceleration bias are both equal to or higher than the threshold.

2. The device according to claim 1, wherein

the state-amount estimation unit (60) estimates, for each of the one or more sensors, the state amount with which a residual error is minimized, the residual error being obtained when the self-position at each of one or more the past times is substituted into a predetermined relational expression, and

the relational expression is an equation for calculating the self-position at the target time based on the self-position at the past time, the observation value of a corresponding sensor, the state amount of the corresponding sensor, and a time difference between the past time and the target time.

3. The device according to claim 2, wherein

the state-amount estimation unit (60) estimates the state amount by a non-linear least-square method, and

the confidence-degree calculation unit (62) acquires a covariance matrix of a plurality of different components of the estimated state amount, and

calculates, as the confidence degree, reciprocal of a sum of diagonal components of the acquired covariance matrix.

4. The device according to claim 2, wherein

the moving object device (10) further includes a second sensor for observing an observation value corresponding to the state amount, and

the confidence-degree calculation unit (62) calculates the confidence degree by comparing the observation value of the second sensor with the estimated state amount.

5. The device according to claim 1, wherein, when the first scheme is selected, the self-position estimation unit (64) estimates the self-position at the target time based on the self-position at the past time, associates each of one or more feature points included in the captured image at the target time with a corresponding feature point included in the captured image at the past time based on the estimated self-position at the target time, and adjusts the estimated self-position at the target time to minimize a reprojection error, the reprojection error representing an evaluation value of an error between a pixel position of each of the one or more feature points included in the captured image at the target time and a pixel position at which the corresponding feature point included in the captured image at the past time is reprojected onto the captured image at the target time based on the estimated self-position at the target time.

6. The device according to claim 5, wherein, when the second scheme is selected, the self-position estimation unit (64) estimates a translation component of the self-position at the target time based on a translation component of the self-position at the past time, estimates a rotation component of the self-position at the target time based on a rotation component of the self-position at the past time, the measured angular velocity, and the estimated angular velocity bias, associates each of one or more feature points included in the captured image at the target time with the corresponding feature point included in the captured image at the past time based on the estimated self-position at the target time, and adjusts the estimated self-position at the target time to minimize a sum of the reprojection error and a first residual error in a rotation-component motion equation, the first residual error in the rotation-component motion equation representing an evaluation value of a residual error obtained when a rotation component of the self-position at the past time, the measured angular velocity, and the estimated angular velocity bias are substituted into the rotation-component motion equation.

7. The device according to claim 6, wherein, when the third scheme is selected, the self-position estimation unit (64) estimates the translation component of the self-position at the target time based on the translation component of the self-position at the past time, the measured acceleration, the estimated speed, the estimated gravitational acceleration, and the estimated acceleration bias, estimates the rotation component of the self-position at the target time based on the rotation component of the self-position at the past time, the measured angular velocity, and the estimated angular velocity bias, associates each of one or more feature points included in the captured image at the target time with the corresponding feature point included in the captured image at the past time based on the estimated self-position at the target time, and adjusts the estimated self-position at the target time to minimize a sum of the reprojection error, the first residual error in the rotation-component motion equation, and a second residual error in a translation-component motion equation, the second residual error in the translation-component motion equation representing an evaluation value of a residual error obtained when the translation component of the self-position at the past time, the measured acceleration, the estimated speed, the estimated gravitational acceleration, and the estimated acceleration bias are substituted into the translation-component motion equation.

8. The device according to claim 7, wherein

the state-amount estimation unit (60) estimates the angular velocity bias with which the first residual error is minimized, the first residual error being obtained when the rotation component of the self-position at the past time is substituted into the rotation component motion equation, and
the rotation-component motion equation is expressed by Expression (1) below:

$$R(t+\Delta t) = R(t)\mathrm{x}\mathrm{Exp}((\omega(t) - b_g)\,\Delta t) \ldots (1)$$

where

$R(t+\Delta t)$ represents the rotation component of the self-position at the target time,
$R(t)$ represents the rotation component of the self-position at the past time, $\omega(t)$ represents the measured angular velocity,
b_g represents the angular velocity bias, and
Δt represents a time difference between the past time and the target time.

9. A position estimation method implemented by a computer to estimate a self-position of a moving object device (10) provided with one or more sensors (22) for observing information related to movement and further provided with an image capturing device (21) capturing an image of vicinity of the moving object device; the self-position including a translation component and a rotation component; the one or more sensors including an angular velocity sensor (31) and an acceleration sensor (32), the angular velocity sensor measures the angular velocity of the moving object device (10) at the target time, and the acceleration sensor measures the acceleration of the moving object device (10) at the target time;
the method comprising:

an estimating step of estimating a state amount representing a state of each of the one or more sensors based on

an observation value of the corresponding sensor;
a calculating step of calculating a confidence degree representing a degree of confidence of the state amount of each of the one or more sensors;
a selecting step of selecting one or more target sensors from among the one or more sensors based on the confidence degree of the state amount of each of the one or more sensors;
a second estimating step of estimating the self-position based on the observation value and the state amount of each of the selected one or more target sensors;
wherein:

when the one or more sensors include one or more target sensors whose confidence degrees are equal to or higher than a predetermined threshold, the selecting step includes selecting, as the one or more target sensors from among the one or more sensors, one or more sensors whose confidence degrees of the state amounts are equal to or higher than the threshold; and the estimating step includes estimating the self-position at a target time based on a captured image captured by the image capturing device at the target time, the captured image at a past time before the target time, the self-position at the past time, and the observation value and the state amount of each of the selected one or more target sensors;
when the one or more sensors include none of the one or more sensors whose confidence degrees are equal to or higher than the threshold, the estimating step includes estimating the self-position at the target time based on the captured image at the target time, the captured image at the past time, and the self-position at the past time;
wherein the estimating step further includes estimating, as the state amount of the angular velocity sensor, an angular velocity bias of the moving object device, and estimating, as the state amount of the acceleration sensor, the speed and gravitational acceleration of the moving object device and an acceleration bias of the moving object device;
wherein the selecting step further includes estimating the self-position at the target time based on a first scheme in which the self-position at the target time is estimated based on the captured image at the target time, the captured image at the past time, and the self-position at the past time,
a second scheme in which the self-position at the target time is estimated based on the captured image at the target time, the measured angular velocity, the estimated angular velocity bias, the captured image at the past time, and the self-position at the past time, or
a third scheme in which the self-position at the target time is estimated based on the captured image at the target time, the measured angular velocity, the estimated angular velocity bias, the measured acceleration, the estimated speed, the estimated gravitational acceleration, the estimated acceleration bias, the captured image at the past time, and the self-position at the past time, and
selecting the first scheme when the confidence degree of the angular velocity bias is not equal to or higher than the threshold,
selecting the second scheme when the confidence degree of the angular velocity bias is equal to or higher than the threshold and the confidence degree of the acceleration bias is not equal to or higher than the threshold, and
selecting the third scheme when the confidence degree of the angular velocity bias and the confidence degree of the acceleration bias are both equal to or higher than the threshold.

10. A computer-readable program executed by a computer to estimate a self-position of a moving object device (10) provided with one or more sensors (22) for observing information related to movement, and further provided with an image capturing device (21) capturing an image of vicinity of the moving object device;

the self-position including a translation component and a rotation component;
the one or more sensors including an angular velocity sensor (31) and an acceleration sensor (32), the angular velocity sensor measures the angular velocity of the moving object device (10) at the target time, and the acceleration sensor measures the acceleration of the moving object device (10) at the target time;
the computer-readable program comprising instructions that cause the computer to perform:

an estimating step of estimating a state amount representing a state of each of the one or more sensors based on an observation value of the corresponding sensor;
a calculating step of calculating a confidence degree representing a degree of confidence of the state amount of each of the one or more sensors;
a selecting step of selecting one or more target sensors from among the one or more sensors based on the confidence degree of the state amount of each of the one or more sensors; and

a second estimating step of estimating the self-position based on the observation value and the state amount of each of the selected one or more target sensors;
wherein:

when the one or more sensors include one or more target sensors whose confidence degrees are equal to or higher than a predetermined threshold, the selecting step includes selecting, as the one or more target sensors from among the one or more sensors, one or more sensors whose confidence degrees of the state amounts are equal to or higher than the threshold; and the estimating step includes estimating the self-position at a target time based on a captured image captured by the image capturing device at the target time, the captured image at a past time before the target time, the self-position at the past time, and the observation value and the state amount of each of the selected one or more target sensors;
when the one or more sensors include none of the one or more sensors whose confidence degrees are equal to or higher than the threshold, the estimating step includes estimating the self-position at the target time based on the captured image at the target time, the captured image at the past time, and the self-position at the past time;
wherein the estimating step further includes estimating, as the state amount of the angular velocity sensor, an angular velocity bias of the moving object device, and estimating, as the state amount of the acceleration sensor, the speed and gravitational acceleration of the moving object device and an acceleration bias of the moving object device;
wherein the selecting step further includes estimating the self-position at the target time based on a first scheme in which the self-position at the target time is estimated based on the captured image at the target time, the captured image at the past time, and the self-position at the past time,
a second scheme in which the self-position at the target time is estimated based on the captured image at the target time, the measured angular velocity, the estimated angular velocity bias, the captured image at the past time, and the self-position at the past time, or
a third scheme in which the self-position at the target time is estimated based on the captured image at the target time, the measured angular velocity, the estimated angular velocity bias, the measured acceleration, the estimated speed, the estimated gravitational acceleration, the estimated acceleration bias, the captured image at the past time, and the self-position at the past time, and
selecting the first scheme when the confidence degree of the angular velocity bias is not equal to or higher than the threshold,
selecting the second scheme when the confidence degree of the angular velocity bias is equal to or higher than the threshold and the confidence degree of the acceleration bias is not equal to or higher than the threshold, and
selecting the third scheme when the confidence degree of the angular velocity bias and the confidence degree of the acceleration bias are both equal to or higher than the threshold.

Patentansprüche

1. Positionsschätzungsvorrichtung (50) zum Schätzen einer Selbstposition einer Bewegungsobjektvorrichtung (10), die mit einem oder mehreren Sensoren (22) zum Beobachten von bewegungsbezogenen Informationen und ferner mit einer Bildaufnahmevorrichtung (21) versehen ist, die ein Bild der Umgebung der Bewegungsobjektvorrichtung (10) aufnimmt; wobei die Selbstposition eine Translationskomponente und eine Rotationskomponente umfasst; der eine oder die mehreren Sensoren einen Winkelgeschwindigkeitssensor (31) und einen Beschleunigungssensor (32) umfassen, wobei der Winkelgeschwindigkeitssensor die Winkelgeschwindigkeit der Bewegungsobjektvorrichtung (10) zum Zielzeitpunkt misst, und der Beschleunigungssensor die Beschleunigung der Bewegungsobjektvorrichtung (10) zum Zielzeitpunkt misst;
wobei die Positionsschätzvorrichtung (50) umfasst:

eine Zustandsschätzungseinheit (60), die konfiguriert ist, einen Zustandsbetrag zu schätzen, der einen Zustand von jedem der einen oder mehreren Sensoren (22) basierend auf einem Beobachtungswert des entsprechenden Sensors repräsentiert;
eine Vertrauensgradberechnungseinheit (62), die konfiguriert ist, einen Vertrauensgrad zu berechnen, der einen Vertrauensgrad des Zustandsbetrags jedes des einen oder der mehreren Sensoren (22) repräsentiert; und
eine Selbstpositionsschätzeinheit (64), die konfiguriert ist, einen oder mehrere Zielsensoren aus dem einen oder den mehreren Sensoren (22) basierend auf dem Vertrauensgrad des Zustandsbetrags von jedem des einen oder der mehreren Sensoren auszuwählen und die Selbstposition basierend auf dem Beobachtungswert und dem

Zustandsbetrag von jedem des ausgewählten einen oder der mehreren Zielsensoren zu schätzen;
wobei:

wenn der eine oder die mehreren Sensoren einen oder mehrere Zielsensoren umfassen, deren Vertrauensgrade gleich oder höher als eine vorbestimmte Schwelle sind, die Selbstpositionsschätzeinheit (64) als den einen oder die mehreren Zielsensoren unter dem einen oder den mehreren Sensoren einen oder mehrere Sensoren auswählt, deren Vertrauensgrade der Zustandsbeträge gleich oder höher als die Schwelle sind;
die Selbstpositionsschätzeinheit (64) die Selbstposition zu einem Zielzeitpunkt basierend auf einem aufgenommenen Bild, das von der Bildaufnahmevorrichtung zu dem Zielzeitpunkt aufgenommen wurde, dem aufgenommenen Bild zu einem vergangenen Zeitpunkt vor dem Zielzeitpunkt, der Selbstposition zu dem vergangenen Zeitpunkt, und dem Beobachtungswert und dem Zustandsbetrag von jedem der ausgewählten ein oder mehreren Zielsensoren schätzt;
wenn der eine oder die mehreren Sensoren keinen der einen oder mehreren Sensoren umfassen, deren Vertrauensgrade gleich oder höher als die Schwelle sind, die Selbstpositionsschätzeinheit (64) die Selbstposition zu der Zielzeit basierend auf dem aufgenommenen Bild zu der Zielzeit, dem aufgenommenen Bild zu der vergangenen Zeit und der Selbstposition zu der vergangenen Zeit schätzt;
wobei die Zustandsbetragsschätzeinheit (60) schätzt: als den Zustandsbetrag des Winkelgeschwindigkeitssensors einen Winkelgeschwindigkeitsbias der Bewegungsobjektvorrichtung und als den Zustandsbetrag des Beschleunigungssensors die Geschwindigkeit und die Gravitationsbeschleunigung der Bewegungsobjektvorrichtung und ein Beschleunigungsbias der Bewegungsobjektvorrichtung; und
wobei die Selbstpositionsschätzeinheit (64) schätzt: die Selbstposition zum Zielzeitpunkt basierend auf
einem ersten Schema, in dem die Selbstposition zum Zielzeitpunkt basierend auf dem aufgenommenen Bild zum Zielzeitpunkt, dem aufgenommenen Bild zu der vergangenen Zeit und der Selbstposition zu der vergangenen Zeit geschätzt wird,
einem zweites Schema, in dem die Selbstposition zum Zielzeitpunkt geschätzt wird basierend auf dem aufgenommenen Bild zu dem Zielzeitpunkt, der gemessenen Winkelgeschwindigkeit, dem geschätzten Winkelgeschwindigkeit, dem aufgenommenen Bild zu dem vergangenen Zeitpunkt und der eigenen Position zu dem vergangenen Zeitpunkt geschätzt wird, oder
einem dritten Schema, in dem die eigene Position zum Zielzeitpunkt geschätzt wird basierend auf dem erfassten Bild zum Zielzeitpunkt, der gemessenen Winkelgeschwindigkeit, dem geschätzten Winkelgeschwindigkeitsbias, der gemessenen Beschleunigung, der geschätzten Geschwindigkeit, der geschätzten Gravitationsbeschleunigung, dem geschätzten Beschleunigungsbias, dem aufgenommenen Bild zu der vergangenen Zeit und der Selbstposition zu der vergangenen Zeit geschätzt wird, und
das erste Schema auswählt, wenn der Vertrauensgrad des Winkelgeschwindigkeitsbias nicht gleich der Schwelle oder höher als diese ist,
das zweite Schema auswählt, wenn der Vertrauensgrad des Winkelgeschwindigkeitsbias gleich oder höher als die Schwelle ist und der Vertrauensgrad des Beschleunigungsbias nicht gleich oder höher als die Schwelle ist, und
das dritte Schema auswählt, wenn der Vertrauensgrad des Winkelgeschwindigkeitsbias und der Vertrauensgrad des Beschleunigungsbias beide gleich oder größer als die Schwelle sind.

2. Vorrichtung nach Anspruch 1, wobei

die Zustandsbetragsschätzeinheit (60) für jeden der einen oder mehreren Sensoren den Zustandsbetrag schätzt, mit dem ein Restfehler minimiert wird, wobei der Restfehler erhalten wird, wenn die Selbstposition zu jedem der einen oder mehreren vergangenen Zeitpunkte in einen vorbestimmten Beziehungsausdruck eingesetzt wird, und
der relationale Ausdruck eine Gleichung zum Berechnen der Selbstposition zum Zielzeitpunkt basierend auf der Selbstposition zum vergangenen Zeitpunkt, dem Beobachtungswert eines entsprechenden Sensors, dem Zustandsbetrag des entsprechenden Sensors und einer zeitlichen Differenz zwischen dem vergangenen Zeitpunkt und dem Zielzeitpunkt ist.

3. Vorrichtung nach Anspruch 2, wobei

die Zustandsbetragsschätzeinheit (60) den Zustandsbetrag durch ein nichtlineares Verfahren der kleinsten Quadrate schätzt, und
die Vertrauensgradberechnungseinheit (62) eine Kovarianzmatrix einer Vielzahl verschiedener Komponenten des geschätzten Zustandsbetrages erhält, und

berechnet als Vertrauensgrad den Kehrwert einer Summe von diagonalen Komponenten der erfassten Kovarianzmatrix.

4. Vorrichtung nach Anspruch 2, wobei

die Bewegungsobjektvorrichtung (10) ferner einen zweiten Sensor zur Beobachtung eines Beobachtungswertes umfasst, der dem Zustandsbetrag entspricht, und
die Vertrauensgradberechnungseinheit (62) den Vertrauensgrad berechnet, indem sie den Beobachtungswert des zweiten Sensors mit dem geschätzten Zustandsbetrag vergleicht.

5. Vorrichtung nach Anspruch 1, wobei, wenn das erste Schema ausgewählt ist, die
Selbstpositionsschätzeinheit (64) die Selbstposition zum Zielzeitpunkt basierend auf der Selbstposition zum vergangenen Zeitpunkt schätzt, jeden von einem oder mehreren Merkmalspunkten, die in dem aufgenommenen Bild zum Zielzeitpunkt enthalten sind, mit einem entsprechenden Merkmalspunkt, der in dem aufgenommenen Bild zum vergangenen Zeitpunkt enthalten ist, basierend auf der geschätzten Selbstposition zum Zielzeitpunkt assoziiert, und die geschätzte Selbstposition zum Zielzeitpunkt anpasst, um einen Reprojektionsfehler zu minimieren, wobei der Reprojektionsfehler einen Evaluierungswert eines Fehlers zwischen einer Pixelposition jedes des einen oder der mehreren Merkmalspunkte, die in dem aufgenommenen Bild zum Zielzeitpunkt enthalten sind, und einer Pixelposition darstellt, an der der entsprechende Merkmalspunkt, der in dem aufgenommenen Bild zum vergangenen Zeitpunkt enthalten ist, basierend auf der geschätzten Selbstposition zum Zielzeitpunkt auf das aufgenommene Bild zum Zielzeitpunkt reprojiziert wird.

6. Vorrichtung nach Anspruch 5, wobei, wenn das zweite Schema ausgewählt ist, die
Selbstpositionsschätzeinheit (64) eine Translationskomponente der Selbstposition zum Zielzeitpunkt basierend auf einer Translationskomponente der Selbstposition zum vergangenen Zeitpunkt schätzt, eine Rotationskomponente der Selbstposition zum Zielzeitpunkt basierend auf einer Rotationskomponente der Selbstposition zum vergangenen Zeitpunkt, der gemessenen Winkelgeschwindigkeit und den geschätzten Winkelgeschwindigkeitsbias schätzt, jeden von einem oder mehreren Merkmalspunkten, die in dem aufgenommenen Bild zum Zielzeitpunkt enthalten sind, mit dem entsprechenden Merkmalspunkt, der in dem aufgenommenen Bild zum vergangenen Zeitpunkt enthalten ist, basierend auf der geschätzten Selbstposition zum Zielzeitpunkt assoziiert, und die geschätzte Selbstposition zum Zielzeitpunkt anpasst, um eine Summe des Reprojektionsfehlers und eines ersten Restfehlers in einer Rotationskomponentenbewegungsgleichung zu minimieren, wobei der erste Restfehler in der Rotationskomponentenbewegungsgleichung einen Evaluierungswert eines Restfehlers darstellt, der erhalten wird, wenn eine Rotationskomponente der Selbstposition zum vergangenen Zeitpunkt, die gemessene Winkelgeschwindigkeit und der geschätzte Winkelgeschwindigkeitsbias in die Rotationskomponentenbewegungsgleichung eingesetzt werden.

7. Vorrichtung nach Anspruch 6, wobei, wenn das dritte Schema ausgewählt ist, die
Selbstpositionsschätzeinheit (64) die Translationskomponente der Selbstposition zum Zielzeitpunkt basierend auf der Translationskomponente der Selbstposition zum vergangenen Zeitpunkt, der gemessenen Beschleunigung, der geschätzten Geschwindigkeit, der geschätzten Gravitationsbeschleunigung und dem geschätzten Beschleunigungsbias schätzt, die Rotationskomponente der Selbstposition zum Zielzeitpunkt basierend auf der Rotationskomponente der Selbstposition zum vergangenen Zeitpunkt, der gemessenen Winkelgeschwindigkeit und dem geschätzten Winkelgeschwindigkeitsbias schätzt, jeden von einem oder mehreren Merkmalspunkten, die in dem aufgenommenen Bild zum Zielzeitpunkt enthalten sind, mit dem entsprechenden Merkmalspunkt, der in dem aufgenommenen Bild zum vergangenen Zeitpunkt enthalten ist, basierend auf der geschätzten Selbstposition zum Zielzeitpunkt assoziiert, und die geschätzte Selbstposition zum Zielzeitpunkt anpasst, um eine Summe des Reprojektionsfehlers, des ersten Restfehlers in der Rotationskomponentenbewegungsgleichung und eines zweiten Restfehlers in einer Translationskomponentenbewegungsgleichung zu minimieren, wobei der zweite Restfehler in der Translationskomponentenbewegungsgleichung einen Evaluierungswert eines Restfehlers darstellt, der erhalten wird, wenn die Translationskomponente der Selbstposition zum vergangenen Zeitpunkt, die gemessene Beschleunigung, die geschätzte Geschwindigkeit, die geschätzte Gravitationsbeschleunigung und der geschätzte Beschleunigungsbias in die Translationskomponentenbewegungsgleichung eingesetzt werden.

8. Vorrichtung nach Anspruch 7, wobei

die Zustandsbetragsschätzeinheit (60) den Winkelgeschwindigkeitsbias schätzt, mit dem der erste Restfehler minimiert wird, wobei der erste Restfehler erhalten wird, wenn die Rotationskomponente der Selbstposition zu dem vergangenen Zeitpunkt in die Rotationskomponentenbewegungsgleichung eingesetzt wird, und die Rotationskomponentenbewegungsgleichung durch den nachstehenden Ausdruck (1) ausgedrückt wird:

$$R(t+\Delta t) = R(t) x Exp((\omega(t) - b_g) \Delta t) \ ... \ (1)$$

wobei
$R(t+\Delta t)$ die Rotationskomponente der Eigenposition zum Zielzeitpunkt repräsentiert,
$R(t)$ die Rotationskomponente der Selbstposition zum vergangenen Zeitpunkt repräsentiert,
$\omega(t)$ die gemessene Winkelgeschwindigkeit repräsentiert,
b_g den Winkelgeschwindigkeitsbias repräsentiert, und
Δt eine Differenz zwischen dem vergangenen Zeitpunkt und dem Zielzeitpunkt repräsentiert.

9. Positionsschätzverfahren, das von einem Computer implementiert wird, um eine Selbstposition einer Bewegungsobjektvorrichtung (10) zu schätzen, die mit einem oder mehreren Sensoren (22) zum Beobachten von bewegungsbezogenen Informationen und ferner mit einer Bildaufnahmevorrichtung (21) versehen ist, die ein Bild der Umgebung der Bewegungsobjektvorrichtung aufnimmt;

wobei die Selbstpositionierung eine Translationskomponente und eine Rotationskomponente umfasst;
wobei der eine oder die mehreren Sensoren einen Winkelgeschwindigkeitssensor (31) und einen Beschleunigungssensor (32) umfassen, wobei der Winkelgeschwindigkeitssensor die Winkelgeschwindigkeit der Bewegungsobjektvorrichtung (10) zum Zielzeitpunkt misst, und der Beschleunigungssensor die Beschleunigung der Bewegungsobjektvorrichtung (10) zum Zielzeitpunkt misst;
wobei das Verfahren umfasst:

einen Schätzschritt des Schätzens eines Zustandsbetrages, der einen Zustand jedes der einen oder mehreren Sensoren repräsentiert, basierend auf einem Beobachtungswert des entsprechenden Sensors;
einen Berechnungsschritt des Berechnens eines Vertrauensgrades, der einen Grad des Vertrauens in den Zustandsbetrag jedes des einen oder der mehreren Sensoren repräsentiert;
einen Auswahlschritt des Auswählens eines oder mehrerer Zielsensoren aus dem einen oder den mehreren Sensoren basierend auf dem Vertrauensgrad des Zustandsbetrages jedes der einen oder mehreren Sensoren;
einen zweiten Schätzschritt zum Schätzen der Selbstpositionierung basierend auf dem Beobachtungswert und dem Zustandsbetrag jedes der ausgewählten ein oder mehreren Positionssensoren;
wobei:

wenn der eine oder die mehreren Sensoren einen oder mehrere Zielsensoren umfassen, deren Vertrauensgrade gleich oder höher als eine vorbestimmte Schwelle sind, der Auswahlschritt das Auswählen eines oder mehrerer Sensoren als den einen oder die mehreren Zielsensoren aus dem einen oder den mehreren Sensoren umfasst, deren Vertrauensgrade der Zustandsbeträge gleich oder höher als die Schwelle sind; und der Schätzschritt das Schätzen der Selbstposition zu einem Zielzeitpunkt basierend auf einem aufgenommenen Bild, das von der Bildaufnahmevorrichtung zu dem Zielzeitpunkt aufgenommen wurde, dem aufgenommenen Bild zu einem vergangenen Zeitpunkt vor dem Zielzeitpunkt, der Selbstposition zu dem vergangenen Zeitpunkt und dem Beobachtungswert und dem Zustandsbetrag von jedem der ausgewählten ein oder mehreren Zielsensoren umfasst;
wenn der eine oder die mehreren Sensoren keinen der einen oder mehreren Sensoren umfassen, deren Vertrauensgrade gleich oder höher als die Schwelle sind, umfasst der Schätzschritt das Schätzen der Selbstpositionierung zu der Zielzeit basierend auf dem aufgenommenen Bild zu der Zielzeit, dem aufgenommenen Bild zu der vergangenen Zeit und der Selbstpositionierung zu der vergangenen Zeit;
wobei der Schätzschritt ferner umfasst: Schätzen, als den Zustandsbetrag des Sensors für die Winkelgeschwindigkeit, eines Winkelgeschwindigkeitsbias der Bewegungsobjektvorrichtung, und Schätzen, als den Zustandsbetrag des Beschleunigungssensors, der Geschwindigkeit und der Gravitationsbeschleunigung der Bewegungsobjektvorrichtung und eines Beschleunigungsbias der Bewegungsobjektvorrichtung;
wobei der Auswahlschritt ferner umfasst: Schätzen der Selbstposition zu dem Zielzeitpunkt basierend auf
einem ersten Schema, in dem die Selbstposition zu dem Zielzeitpunkt geschätzt wird basierend auf dem aufgenommenen Bild zu dem Zielzeitpunkt, dem aufgenommenen Bild zu dem vergangenen Zeitpunkt und der Selbstposition zu dem vergangenen Zeitpunkt,
einem zweiten Schema, in dem die Selbstpositionierung zum Zielzeitpunkt geschätzt wird basierend auf

dem aufgenommenen Bild zu dem Zielzeitpunkt, der gemessenen Winkelgeschwindigkeit, dem geschätzten Winkelgeschwindigkeit, dem aufgenommenen Bild zu der vergangenen Zeit und der Selbstpositionierung zu der vergangenen Zeit geschätzt wird, oder

einem dritten Schema, in dem die Selbstpositionierung zum Zielzeitpunkt geschätzt wird basierend auf dem erfassten Bild zum Zielzeitpunkt, der gemessenen Winkelgeschwindigkeit, dem geschätzten Winkelgeschwindigkeitsbias, der gemessenen Beschleunigung, der geschätzten Geschwindigkeit geschätzten Gravitationsbeschleunigung, dem geschätzten Beschleunigungsbias, dem aufgenommenen Bild zum vergangenen Zeitpunkt und der Selbstpositionierung zum vergangenen Zeitpunkt geschätzt wird, und

Auswählen des ersten Schemas, wenn der Vertrauensgrad des Winkelgeschwindigkeitsbias nicht gleich der Schwelle oder höher als diese ist,

Auswählen des zweiten Schemas, wenn der Vertrauensgrad des Winkelgeschwindigkeitsbias gleich oder höher als die Schwelle ist und der Vertrauensgrad des Beschleunigungsbias nicht gleich oder höher als die Schwelle ist, und

Auswählen des dritten Schemas, wenn der Vertrauensgrad der Winkelgeschwindigkeitsbias und der Vertrauensgrad der Beschleunigungsbias beide gleich oder größer als die Schwelle sind.

10. Computerlesbares Programm, das von einem Computer ausgeführt wird, um eine Selbstposition einer Bewegungsobjektvorrichtung (10) zu schätzen, die mit einem oder mehreren Sensoren (22) zum Beobachten von bewegungsbezogenen Informationen versehen ist, und ferner mit einer Bildaufnahmevorrichtung (21) versehen ist, die ein Bild der Umgebung der Bewegungsobjektvorrichtung aufnimmt;

wobei die Selbstpositionierung eine Translationskomponente und eine Rotationskomponente umfasst;

der eine oder die mehreren Sensoren einen Winkelgeschwindigkeitssensor (31) und einen Beschleunigungssensor (32) umfassen, wobei der Winkelgeschwindigkeitssensor die Winkelgeschwindigkeit der Bewegungsobjektvorrichtung (10) zum Zielzeitpunkt und der Beschleunigungssensor die Beschleunigung der Bewegungsobjektvorrichtung (10) zum Zielzeitpunkt misst;

das computerlesbare Programm Anweisungen umfasst, die den Computer veranlassen, durchzuführen:

einen Schätzschritt des Schätzens eines Zustandsbetrags, der einen Zustand jedes der einen oder mehreren Sensoren repräsentiert, basierend auf einem Beobachtungswert des entsprechenden Sensors;

einen Berechnungsschritt des Berechnens eines Vertrauensgrades, der einen Vertrauensgrad des Zustandsbetrages von jedem des einen oder der mehreren Sensoren repräsentiert;

einen Auswahlschritt des Auswählens eines oder mehrerer Zielsensoren aus dem einen oder den mehreren Sensoren basierend auf dem Vertrauensgrad des Zustandsbetrages jedes des einen oder der mehreren Sensoren; und

einen zweiten Schätzschritt zum Schätzen der Selbstpositionierung basierend auf dem Beobachtungswert und dem Zustandsbetrag jedes der ausgewählten ein oder mehreren Positionssensoren;

wobei:

wenn der eine oder die mehreren Sensoren einen oder mehrere Zielsensoren umfassen, deren Vertrauensgrade gleich oder höher als eine vorbestimmte Schwelle sind, der Auswahlschritt das Auswählen eines oder mehrerer Sensoren als den einen oder die mehreren Zielsensoren aus dem einen oder den mehreren Sensoren umfasst, deren Vertrauensgrade der Zustandsbeträge gleich oder höher als die Schwelle sind; und der Schätzschritt das Schätzen der Selbstposition zu einem Zielzeitpunkt basierend auf einem aufgenommenen Bild, das von der Bildaufnahmevorrichtung zu dem Zielzeitpunkt aufgenommen wurde, dem aufgenommenen Bild zu einem vergangenen Zeitpunkt vor dem Zielzeitpunkt, der Selbstposition zu dem vergangenen Zeitpunkt und dem Beobachtungswert und dem Zustandsbetrag von jedem der ausgewählten ein oder mehreren Zielsensoren umfasst;

wenn der eine oder die mehreren Sensoren keinen der einen oder mehreren Sensoren umfassen, deren Vertrauensgrade gleich oder höher als die Schwelle sind, der Schätzschritt das Schätzen der Selbstpositionierung zu der Zielzeit basierend auf dem aufgenommenen Bild zum Zielzeitpunkt, dem aufgenommenen Bild zu der vergangenen Zeit und der Selbstpositionierung zu der vergangenen Zeit umfasst;

wobei der Schätzschritt ferner umfasst: Schätzen, als den Zustandsbetrag des Sensors für die Winkelgeschwindigkeit, eines Winkelgeschwindigkeitsbias der Bewegungsobjektvorrichtung, und Schätzen, als den Zustandsbetrag des Beschleunigungssensors, der Geschwindigkeit und der Gravitationsbeschleunigung der Bewegungsobjektvorrichtung und eines Beschleunigungsbias der Bewegungsobjektvorrichtung;

wobei der Auswahlschritt ferner umfasst: Schätzen der Selbstposition zu dem Zielzeitpunkt basierend auf

einem ersten Schema, in dem die Selbstposition zu dem Zielzeitpunkt geschätzt wird basierend auf dem aufgenommenen Bild zu dem Zielzeitpunkt, dem aufgenommenen Bild zu dem vergangenen Zeitpunkt und der Selbstposition zu dem vergangenen Zeitpunkt,

einem zweiten Schema, bei dem die Selbstposition zum Zielzeitpunkt basierend auf dem aufgenommenen Bild zum Zielzeitpunkt, der gemessenen Winkelgeschwindigkeit, dem geschätzten Winkelgeschwindigkeitsbias, dem aufgenommenen Bild zum vergangenen Zeitpunkt und der Selbstpositionierung zum vergangenen Zeitpunkt geschätzt wird, oder

einem dritten Schema, bei dem die Selbstposition zum Zielzeitpunkt basierend auf dem aufgenommenen Bild zum Zielzeitpunkt, der gemessenen Winkelgeschwindigkeit, dem geschätzten Winkelgeschwindigkeitsbias, der gemessenen Beschleunigung, der geschätzten Geschwindigkeit, der geschätzten Gravitationsbeschleunigung, dem geschätzten Beschleunigungsbias, dem aufgenommenen Bild zum vergangenen Zeitpunkt, und der Selbstposition zum vergangenen Zeitpunkt geschätzt wird, und

Auswählen des ersten Schemas, wenn der Vertrauensgrad des Winkelgeschwindigkeitsbias nicht gleich der Schwelle oder höher als diese ist,

Auswählen des zweiten Schemas, wenn der Vertrauensgrad des Winkelgeschwindigkeitsbias gleich oder höher als die Schwelle ist und der Vertrauensgrad des Beschleunigungsbias nicht gleich oder höher als die Schwelle ist, und

Auswählen des dritten Schemas, wenn der Vertrauensgrad des Winkelgeschwindigkeitsbias und der Vertrauensgrad des Beschleunigungsbias beide gleich oder größer als die Schwelle sind.

Revendications

1. Un dispositif d'estimation de position (50) pour estimer une position propre d'un dispositif d'objet mobile (10) muni d'un ou plusieurs capteurs (22) pour observer des informations liées au mouvement et muni en outre d'un dispositif de capture d'image (21) capturant une image des environs du dispositif d'objet mobile (10) ; la position propre comprenant une composante de translation et une composante de rotation ; le ou les capteurs comprenant un capteur de vitesse angulaire (31) et un capteur d'accélération (32), le capteur de vitesse angulaire mesure la vitesse angulaire du dispositif d'objet mobile (10) à l'instant cible, et le capteur d'accélération mesure l'accélération du dispositif d'objet mobile (10) à l'instant cible ;
le dispositif d'estimation de position (50) comprenant :

une unité d'estimation de quantité d'état (60) configurée pour estimer une quantité d'état représentant un état de chacun des un ou plusieurs capteurs (22) sur la base d'une valeur d'observation du capteur correspondant ;
une unité de calcul de degré de confiance (62) configurée pour calculer un degré de confiance représentant un degré de confiance de la quantité d'état de chacun des un ou plusieurs capteurs (22) ; et
une unité d'estimation de position propre (64) configurée pour sélectionner un ou plusieurs capteurs cibles parmi le ou les capteurs (22) sur la base du degré de confiance de la quantité d'état de chacun du ou des capteurs, et pour estimer la position propre sur la base de la valeur d'observation et de la quantité d'état de chacun du ou des capteurs cibles sélectionnés;
dans laquelle :

lorsque le ou les capteurs comprennent un ou plusieurs capteurs cibles dont des degrés de confiance sont égaux ou supérieurs à un seuil prédéterminé, l'unité d'estimation de position propre (64) sélectionne, comme le ou les capteurs cibles parmi le ou les capteurs, un ou plusieurs capteurs dont des degrés de confiance des quantités d'état sont égaux ou supérieurs au seuil ;
l'unité d'estimation de position propre (64) estime la position propre à un instant cible sur la base d'une image capturée par le dispositif de capture d'image à l'instant cible, de l'image capturée à un instant passé avant l'instant cible, de la position propre à l'instant passé, et de la valeur d'observation et de la quantité d'état de chacun des un ou plusieurs capteurs cibles sélectionnés ;
lorsque le ou les capteurs n'incluent aucun des un ou plusieurs capteurs dont des degrés de confiance sont égaux ou supérieurs au seuil, l'unité d'estimation de position propre (64) estime la position propre à l'instant cible sur la base de l'image capturée à l'instant cible, de l'image capturée à l'instant passé et la position propre à l'instant passé ;
dans lequel l'unité d'estimation de quantité d'état (60) estime, comme la quantité d'état du capteur de vitesse

angulaire, un biais de vitesse angulaire du dispositif d'objet mobile, et estime, comme la quantité d'état du capteur d'accélération, la vitesse et l'accélération gravitationnelle du dispositif d'objet mobile et un biais d'accélération du dispositif d'objet mobile ; et

dans lequel l'unité d'estimation de position propre (64) estime la position propre à l'instant cible sur la base d'un premier schéma dans lequel la position propre à l'instant cible est estimée sur la base de l'image capturée à l'instant cible, de l'image capturée à l'instant passé et de la position propre à l'instant passé,

d'un deuxième schéma dans lequel la position propre à l'instant cible est estimée sur la base de l'image capturée à l'instant cible, de la vitesse angulaire mesurée, du biais de vitesse angulaire estimé, de l'image capturée à l'instant passé et de la position à l'instant passé, ou

un troisième schéma dans lequel la position à l'instant cible est estimée sur la base de l'image capturée à l'instant cible, de la vitesse angulaire mesurée, du biais de vitesse angulaire estimé, de l'accélération mesurée, de la vitesse estimée, de l'accélération gravitationnelle estimée, du biais d'accélération estimé, de l'image capturée à l'instant passé et de la position propre à l'instant passé, et

sélectionne le premier schéma lorsque le degré de confiance du biais de vitesse angulaire n'est pas égal ou supérieur au seuil,

sélectionne le deuxième schéma lorsque le degré de confiance du biais de vitesse angulaire est égal ou supérieur au seuil et que le degré de confiance du biais d'accélération n'est pas égal ou supérieur au seuil, et

sélectionne le troisième schéma lorsque le degré de confiance du biais de vitesse angulaire et le degré de confiance du biais d'accélération sont tous deux égaux ou supérieurs au seuil.

2. Le dispositif selon la revendication 1, dans lequel

l'unité d'estimation de quantité d'état (60) estime, pour chacun des un ou plusieurs capteurs, la quantité d'état avec laquelle une erreur résiduelle est minimisée, l'erreur résiduelle étant obtenue lorsque la position propre à chacun des un ou plusieurs instants passés est substituée dans une expression relationnelle prédéterminée, et

l'expression relationnelle est une équation pour calculer la position propre à l'instant cible sur la base de la position propre à l'instant passé, de la valeur d'observation d'un capteur correspondant, de la quantité d'état du capteur correspondant et d'une différence de temps entre l'instant passé et l'instant cible.

3. Le dispositif selon la revendication 2, dans lequel

l'unité d'estimation de quantité d'état (60) estime la quantité d'état par un procédé des moindres carrés non linéaire, et

l'unité de calcul de degré de confiance (62) acquiert une matrice de covariance d'une pluralité de différentes composantes de la quantité d'état estimée, et

calcule, comme le degré de confiance, un inverse d'une somme de composantes diagonales de la matrice de covariance acquise.

4. Le dispositif selon la revendication 2, dans lequel

le dispositif d'objet mobile (10) comprend en outre un deuxième capteur pour observer une valeur d'observation correspondant à la quantité d'état, et

l'unité de calcul de degré de confiance (62) calcule le degré de confiance en comparant la valeur d'observation du deuxième capteur avec la quantité d'état estimée.

5. Le dispositif selon la revendication 1, dans lequel, lorsque le premier schéma est sélectionné, l'unité d'estimation de position propre (64) estime la position propre à l'instant cible sur la base de la position propre à l'instant passé, associe chacun d'un ou plusieurs points caractéristiques inclus dans l'image capturée à l'instant cible à un point caractéristique correspondant inclus dans l'image capturée à l'instant passé sur la base de la position propre estimée à l'instant cible, et ajuste la position propre estimée à l'instant cible pour minimiser une erreur de reprojection, l'erreur de reprojection représentant une valeur d'évaluation d'une erreur entre une position de pixel de chacun des un ou plusieurs points caractéristiques inclus dans l'image capturée à l'instant cible et une position de pixel à laquelle le point caractéristique correspondant inclus dans l'image capturée à l'instant passé est reprojetée sur l'image capturée à l'instant cible sur la base de la position propre estimée à l'instant cible.

6. Le dispositif selon la revendication 5, dans lequel, lorsque le deuxième schéma est sélectionné, l'unité d'estimation de position propre (64) estime une composante de translation de la position propre à l'instant cible sur la base d'une composante de translation de la position propre à l'instant passé, estime une composante de rotation de la position propre à l'instant cible sur la base d'une composante de rotation de la position propre à l'instant passé, de la vitesse angulaire mesurée et du biais de vitesse angulaire estimé, associe chacun d'un ou plusieurs points caractéristiques inclus dans l'image capturée à l'instant cible au point caractéristique correspondant inclus dans l'image capturée à l'instant passé sur la base de la position propre estimée à l'instant cible, et ajuste la position propre estimée à l'instant cible pour minimiser une somme de l'erreur de reprojection et d'une première erreur résiduelle dans une équation de mouvement de composante de rotation, la première erreur résiduelle dans l'équation de mouvement de composante de rotation représentant une valeur d'évaluation d'une erreur résiduelle obtenue lorsqu'une composante de rotation de la position propre à l'instant passé, la vitesse angulaire mesurée et le biais de vitesse angulaire estimé sont substitués dans l'équation de mouvement de composante de rotation.

7. Le dispositif selon la revendication 6, dans lequel, lorsque le troisième schéma est sélectionné, l'unité d'estimation de position propre (64) estime la composante de translation de la position propre à l'instant cible sur la base de la composante de translation de la position propre à l'instant passé, de l'accélération mesurée, de la vitesse estimée, de l' accélération gravitationnelle estimée et du biais d'accélération estimé, estime la composante de rotation de la position propre à l'instant cible sur la base de la composante de rotation de la position propre à l'instant passé, de la vitesse angulaire mesurée et du biais de vitesse angulaire estimé, associe chacun d'un ou plusieurs points caractéristiques inclus dans l'image capturée à l'instant cible au point caractéristique correspondant inclus dans l'image capturée à l'instant passé en sur la base de la position propre estimée à l'instant cible, et ajuste la position propre estimée à l'instant cible pour minimiser une somme de l'erreur de reprojection, de la première erreur résiduelle dans l'équation de mouvement de composante de rotation, et d'une deuxième erreur résiduelle dans une équation de mouvement de composante de translation, la deuxième erreur résiduelle dans l'équation de mouvement de composante de translation représentant une valeur d'évaluation d'une erreur résiduelle obtenue lorsque la composante de translation de la position propre à l'instant passé, l'accélération mesurée, la vitesse estimée, l'accélération gravitationnelle estimée et le biais d'accélération estimé sont substitués dans l'équation de mouvement de composante de translation.

8. Le dispositif selon la revendication 7, dans lequel

l'unité d'estimation de quantité d'état (60) estime le biais de vitesse angulaire avec lequel la première erreur résiduelle est minimisée, la première erreur résiduelle étant obtenue lorsque la composante de rotation de la position propre à l'instant passé est substituée dans l'équation de mouvement de composante de rotation, et l'équation de mouvement de composante de rotation est exprimée par l'expression (1) ci-dessous :

$$R(t+\Delta t) = R(t) \times \mathrm{Exp}((\omega(t) - \boldsymbol{b_g})\ \Delta t)\ \ldots\ (1)$$

où

$R(t+\Delta t)$ représente la composante de rotation de la position propre à l'instant cible,
$R(t)$ représente la composante de rotation de la position propre à l'instant passé, $\omega(t)$ représente la vitesse angulaire mesurée,
$\boldsymbol{b_g}$ représente le biais de vitesse angulaire, et
Δt représente un écart de temps entre l'instant passé et l'instant cible.

9. Un procédé d'estimation de position mis en œuvre par un ordinateur pour estimer une position propre position d'un dispositif d'objet mobile (10) muni d'un ou plusieurs capteurs (22) pour observer des informations liées au mouvement et muni en outre d'un dispositif de capture d'image (21) capturant une image des environs du dispositif d'objet mobile;
la position propre comprenant une composante de translation et une composante de rotation;
le ou les capteurs comprenant un capteur de vitesse angulaire (31) et un capteur d'accélération (32), le capteur de vitesse angulaire mesure la vitesse angulaire du dispositif d'objet mobile (10) à l'instant cible, et le capteur d'accélération mesure l'accélération du dispositif d'objet mobile (10) à l'instant cible ;
le procédé comprenant :

une étape d'estimation consistant à estimer une quantité d'état représentant un état de chacun des un ou plusieurs capteurs sur la base d'une valeur d'observation du capteur correspondant ;
une étape de calcul consistant à calculer un degré de confiance représentant un degré de confiance de la quantité d'état de chacun des un ou plusieurs capteurs ;
une étape de sélection consistant à sélectionner un ou plusieurs capteurs cibles parmi le ou les capteurs sur la

base du degré de confiance de la quantité d'état de chacun des un ou plusieurs capteurs ;
une deuxième étape d'estimation consistant à estimer la position propre sur la base de la valeur d'observation et de la quantité d'état de chacun des un ou plusieurs capteurs cibles sélectionnés ;
dans laquelle :

lorsque le ou les capteurs comprennent un ou plusieurs capteurs cibles dont des degrés de confiance sont égaux ou supérieurs à un seuil prédéterminé, l'étape de sélection comprend la sélection, comme le ou les capteurs cibles parmi le ou les capteurs, d'un ou plusieurs capteurs dont des degrés de confiance des quantités d'état sont égaux ou supérieurs au seuil ; et l'étape d'estimation comprend l'estimation de la position propre à un instant cible sur la base d'une image capturée par le dispositif de capture d'image à l'instant cible, de l'image capturée à un instant passé avant l'instant cible, de la position propre à l'instant passé et de la valeur d'observation et de la quantité d'état de chacun des un ou plusieurs capteurs cibles sélectionnés ;
lorsque le ou les capteurs n'incluent aucun des un ou plusieurs capteurs dont des degrés de confiance sont égaux ou supérieurs au seuil, l'étape d'estimation inclut l'estimation de la position propre à l'instant cible sur la base de l'image capturée à l'instant cible, de l'image capturée à l'instant passé et de la position propre à l'instant passé ;
dans lequel l'étape d'estimation comprend en outre l'estimation, en tant que la quantité d'état du capteur de vitesse angulaire, d'un biais de vitesse angulaire du dispositif objet mobile, et l'estimation, en tant que la quantité d'état du capteur d'accélération, de la vitesse et de l'accélération gravitationnelle du dispositif d'objet mobile et d'un biais d'accélération du dispositif d'objet mobile ;
dans lequel l'étape de sélection comprend en outre l'estimation de la position propre à l'instant cible sur la base d'un premier schéma dans lequel la position propre à l'instant cible est estimée sur la base de l'image capturée à l'instant cible, de l'image capturée à l'instant passé et de la position propre à l'instant passé,
d'un deuxième schéma dans lequel la position propre à l'instant cible est estimée sur la base de l'image capturée à l'instant cible, de la vitesse angulaire mesurée, du biais de vitesse angulaire estimé, de l'image capturée à l'instant passé et de la position propre à l'instant passé, ou
d'un troisième schéma dans lequel la position propre à l'instant cible est estimée sur la base de l'image capturée à l'instant cible, de la vitesse angulaire mesurée, du biais de vitesse angulaire estimé, de l'accélération mesurée, de la vitesse estimée, de l' accélération gravitationnelle estimée, du biais d'accélération estimé, de l'image capturée à l'instant passé et de la position propre à l'instant passé, et
la sélection du premier schéma lorsque le degré de confiance du biais de vitesse angulaire n'est pas égal ou supérieur au seuil,
la sélection du deuxième schéma lorsque le degré de confiance du biais de vitesse angulaire est égal ou supérieur au seuil et que le degré de confiance du biais d'accélération n'est pas égal ou supérieur au seuil, et
la sélection du troisième schéma lorsque le degré de confiance du biais de vitesse angulaire et le degré de confiance du biais d'accélération sont tous deux égaux ou supérieurs au seuil.

10. Un programme lisible par ordinateur exécuté par un ordinateur pour estimer une position propre d'un dispositif d'objet mobile (10) muni d'un ou plusieurs capteurs (22) pour observer des informations liées au mouvement, et muni en outre d'un dispositif de capture d'image (21) capturant une image des environs de l'objet mobile ; la position propre comprenant une composante de translation et une composante de rotation;
le ou les capteurs comprenant un capteur de vitesse angulaire (31) et un capteur d'accélération (32), le capteur de vitesse angulaire mesure la vitesse angulaire de dispositif d'objet mobile (10) à l'instant cible, et le capteur d'accélération mesure l'accélération du dispositif d'objet mobile (10) à l'instant cible ;
le programme lisible par ordinateur comprenant des instructions qui font que l'ordinateur exécute :

une étape d'estimation consistant à estimer une quantité d'état représentant un état de chacun des un ou plusieurs capteurs sur la base d'une valeur d'observation du capteur correspondant ;
une étape de calcul consistant à calculer un degré de confiance représentant un degré de confiance de la quantité d'état de chacun des un ou plusieurs capteurs ;
une étape de sélection consistant à sélectionner un ou plusieurs capteurs cibles parmi le ou les capteurs en sur la base du degré de confiance de la quantité d'état de chacun des un ou plusieurs capteurs ; et
une deuxième étape d'estimation consistant à estimer la position propre sur la base de la valeur d'observation et de la quantité d'état de chacun des un ou plusieurs capteurs cibles sélectionnés ;
dans laquelle :

lorsque le ou les capteurs comprennent un ou plusieurs capteurs cibles dont des degrés de confiance sont égaux ou supérieurs à un seuil prédéterminé, l'étape de sélection comprend la sélection, comme le ou les capteurs cibles parmi le ou les capteurs, d'un ou plusieurs capteurs dont des degrés de confiance des quantités d'état sont égaux ou supérieurs au seuil ; et l'étape d'estimation comprend l'estimation de la position propre à un instant cible sur la base d'une image capturée par le dispositif de capture d'image à l'instant cible, de l'image capturée à un instant passé avant l'instant cible, de la position propre à l'instant passé et de la valeur d'observation et de la quantité d'état de chacun des un ou plusieurs capteurs cibles sélectionnés ;

lorsque le ou les capteurs n'incluent aucun des un ou plusieurs capteurs dont des degrés de confiance sont égaux ou supérieurs au seuil, l'étape d'estimation inclut l'estimation de la position propre à l'instant cible sur la base de l'image capturée à l'instant cible, de l'image capturée à l'instant passé et de la position propre à l'instant passé ;

dans lequel l'étape d'estimation comprend en outre l'estimation, en tant que la quantité d'état du capteur de vitesse angulaire, d'un biais de vitesse angulaire du dispositif d'objet mobile, et l'estimation, en tant que la quantité d'état du capteur d'accélération, de la vitesse et de l'accélération gravitationnelle du dispositif d'objet mobile et un biais d'accélération du dispositif d'objet mobile ;

dans lequel l'étape de sélection comprend en outre l'estimation de la position propre à l'instant cible sur la base d'un premier schéma dans lequel la position propre à l'instant cible est estimée sur la base de l'image capturée à l'instant cible, de l'image capturée à l'instant passé et de la position propre à l'instant passé,

d'un deuxième schéma dans lequel la position propre à l'instant cible est estimée sur la base de l'image capturée à l'instant cible, de la vitesse angulaire mesurée, du biais de vitesse angulaire estimé, de l'image capturée à l'instant passé et de la position propre à l'instant passé, ou

d'un troisième schéma dans lequel la position propre à l'instant cible est estimée sur la base de l'image capturée à l'instant cible, de la vitesse angulaire mesurée, du biais de vitesse angulaire estimé, de l'accélération mesurée, de la vitesse estimée, de l'accélération gravitationnelle estimée, du biais d'accélération estimé, de l'image capturée à l'instant passé et de la position propre à l'instant passé, et

la sélection du premier schéma lorsque le degré de confiance du biais de vitesse angulaire n'est pas égal ou supérieur au seuil,

la sélection du deuxième schéma lorsque le degré de confiance du biais de vitesse angulaire est égal ou supérieur au seuil et que le degré de confiance du biais d'accélération n'est pas égal ou supérieur au seuil, et

la sélection du troisième schéma lorsque le degré de confiance du biais de vitesse angulaire et le degré de confiance du biais d'accélération sont tous deux égaux ou supérieurs au seuil.

FIG.1

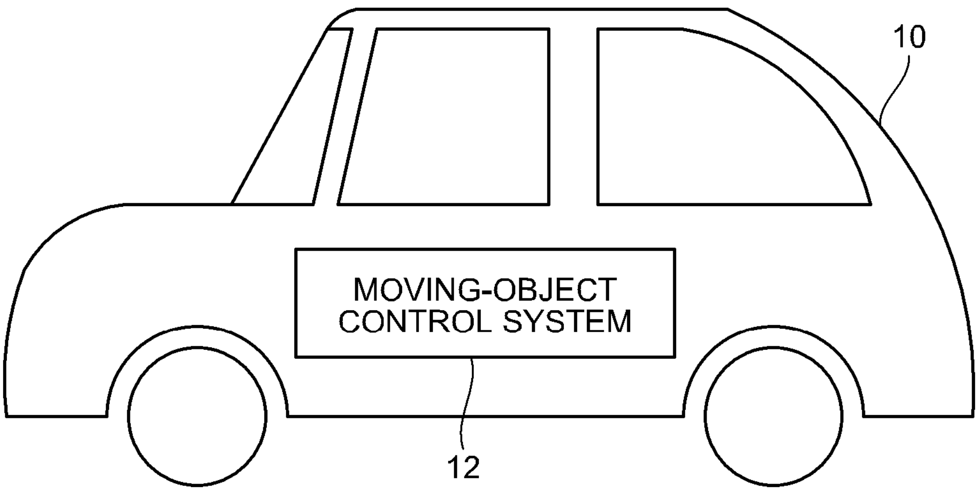
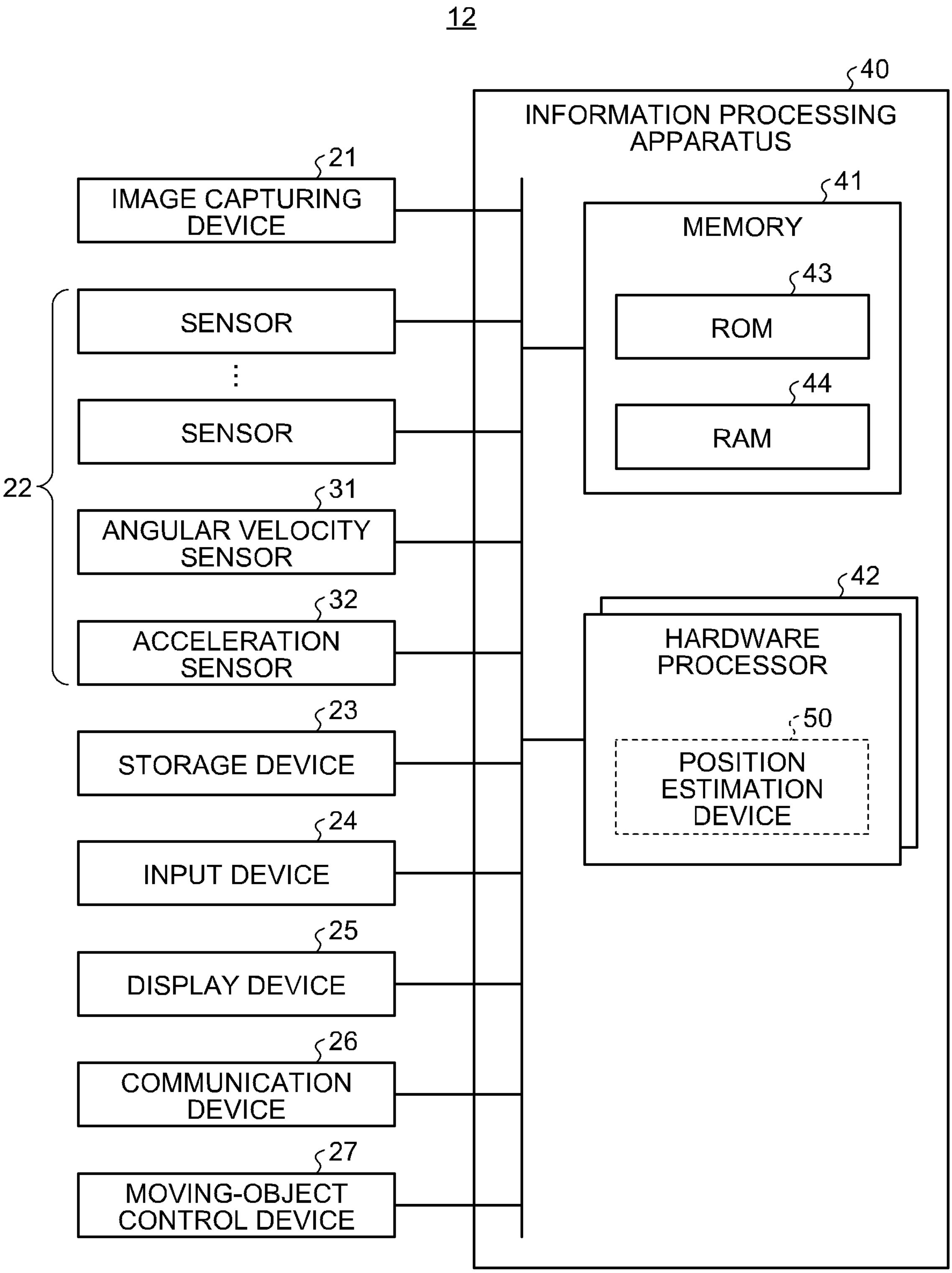


FIG.2


12
40
INFORMATION PROCESSING APPARATUS
21
IMAGE CAPTURING DEVICE
41
MEMORY
43
ROM
44
RAM
SENSOR
⋮
SENSOR
22
31
ANGULAR VELOCITY SENSOR
32
ACCELERATION SENSOR
42
HARDWARE PROCESSOR
50
POSITION ESTIMATION DEVICE
23
STORAGE DEVICE
24
INPUT DEVICE
25
DISPLAY DEVICE
26
COMMUNICATION DEVICE
27
MOVING-OBJECT CONTROL DEVICE

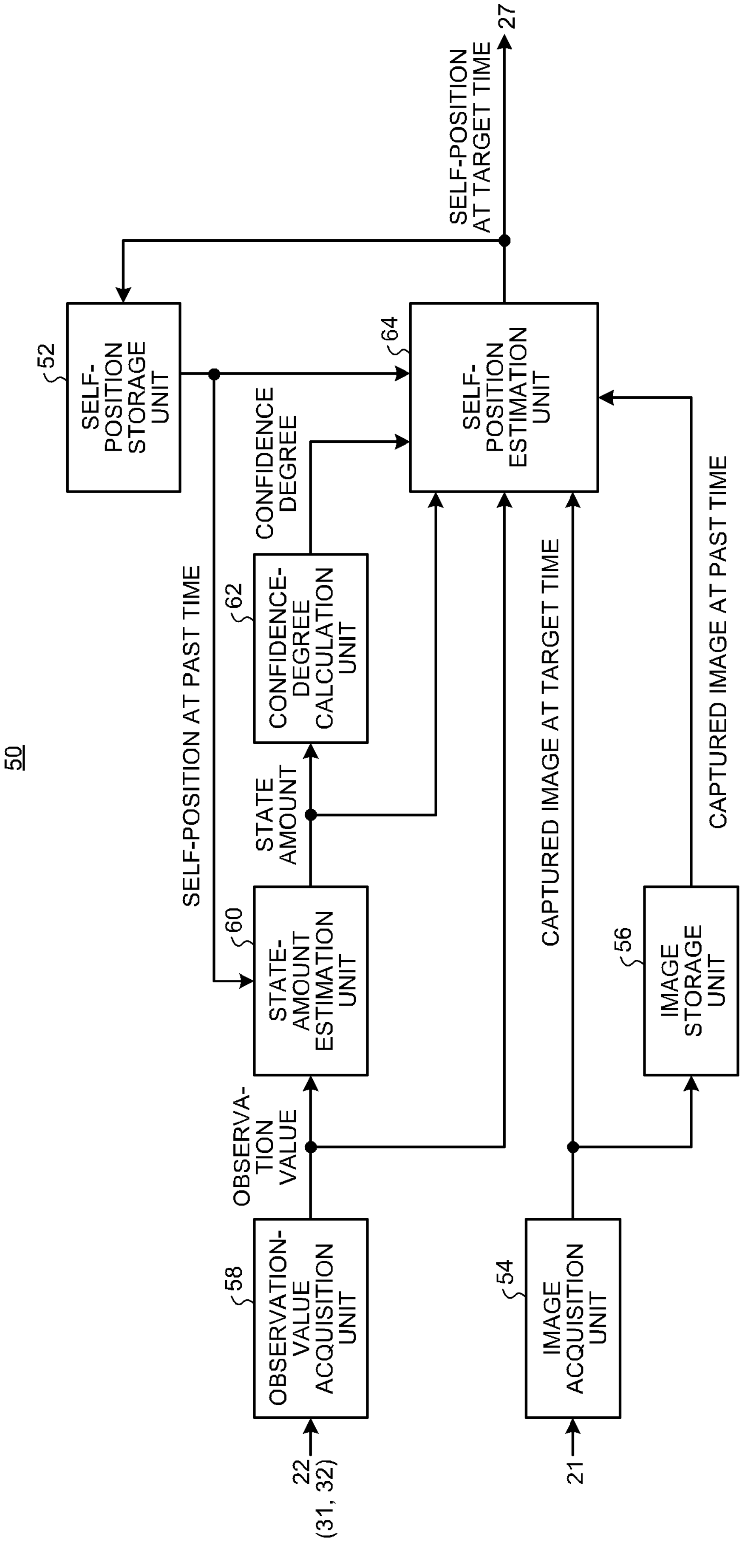

50
22 (31, 32)
58
OBSERVATION-VALUE ACQUISITION UNIT
OBSERVATION VALUE
60
STATE-AMOUNT ESTIMATION UNIT
STATE AMOUNT
62
CONFIDENCE-DEGREE CALCULATION UNIT
CONFIDENCE DEGREE
52
SELF-POSITION STORAGE UNIT
SELF-POSITION AT PAST TIME
64
SELF-POSITION ESTIMATION UNIT
SELF-POSITION AT TARGET TIME
27
21
54
IMAGE ACQUISITION UNIT
CAPTURED IMAGE AT TARGET TIME
56
IMAGE STORAGE UNIT
CAPTURED IMAGE AT PAST TIME

FIG.3

FIG.4

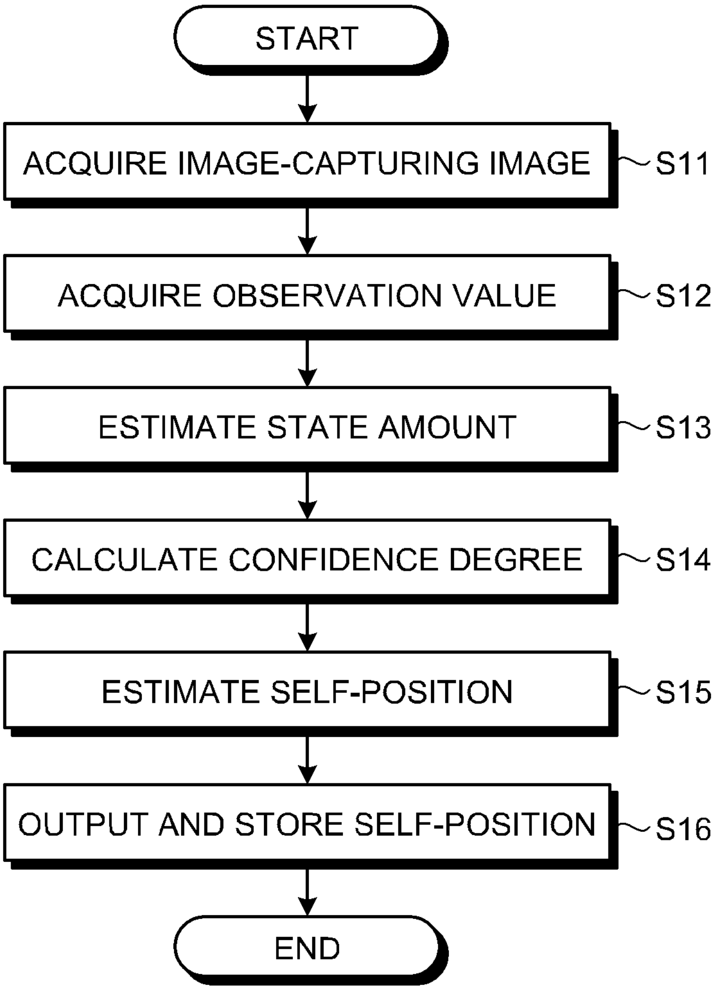

START
ACQUIRE IMAGE-CAPTURING IMAGE
S11
ACQUIRE OBSERVATION VALUE
S12
ESTIMATE STATE AMOUNT
S13
CALCULATE CONFIDENCE DEGREE
S14
ESTIMATE SELF-POSITION
S15
OUTPUT AND STORE SELF-POSITION
S16
END

FIG.5

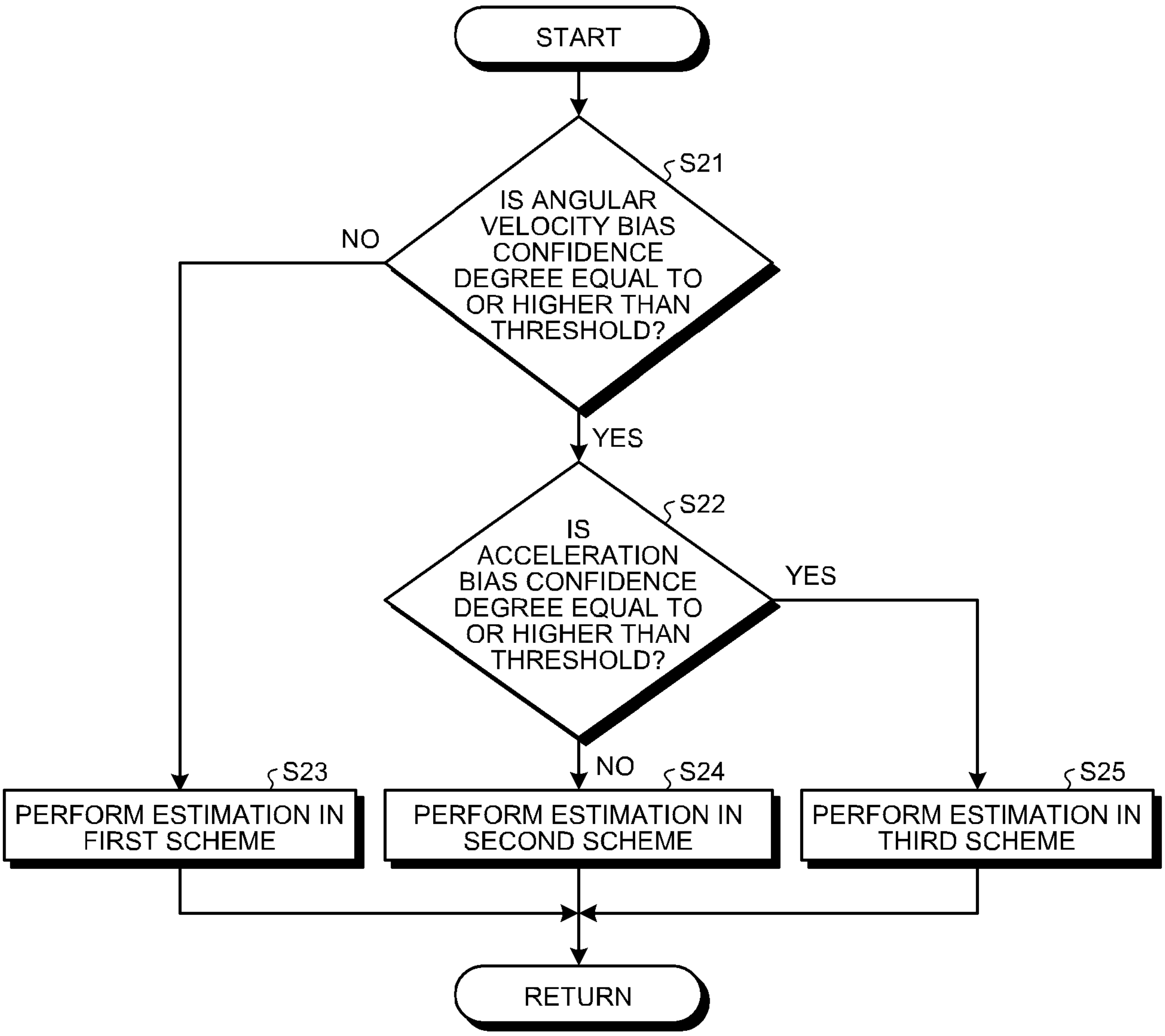

START
S21
IS ANGULAR VELOCITY BIAS CONFIDENCE DEGREE EQUAL TO OR HIGHER THAN THRESHOLD?
NO
YES
S22
IS ACCELERATION BIAS CONFIDENCE DEGREE EQUAL TO OR HIGHER THAN THRESHOLD?
YES
NO
S23
PERFORM ESTIMATION IN FIRST SCHEME
S24
PERFORM ESTIMATION IN SECOND SCHEME
S25
PERFORM ESTIMATION IN THIRD SCHEME
RETURN

FIG.6

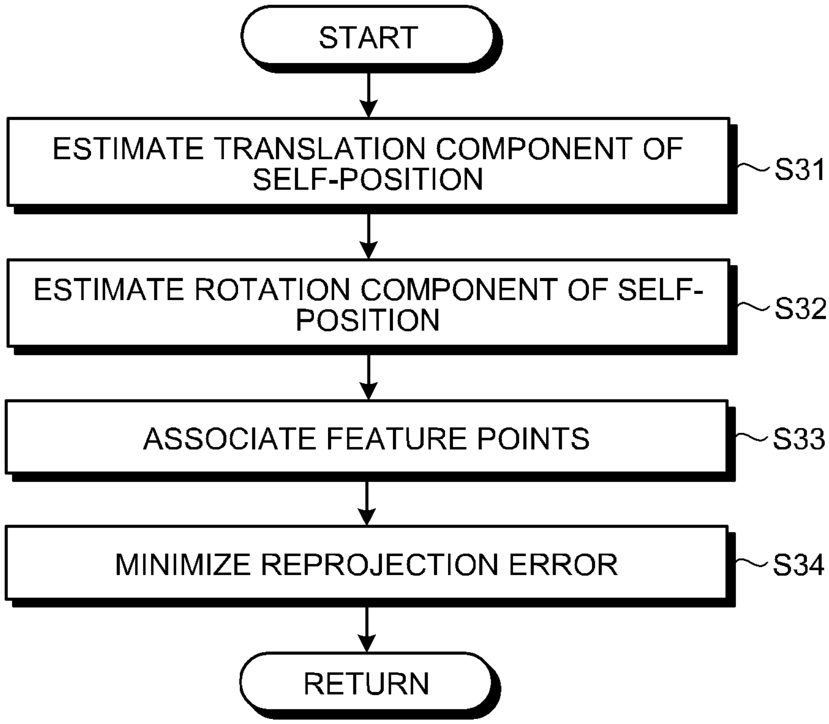

START
ESTIMATE TRANSLATION COMPONENT OF SELF-POSITION
S31
ESTIMATE ROTATION COMPONENT OF SELF-POSITION
S32
ASSOCIATE FEATURE POINTS
S33
MINIMIZE REPROJECTION ERROR
S34
RETURN

FIG.7

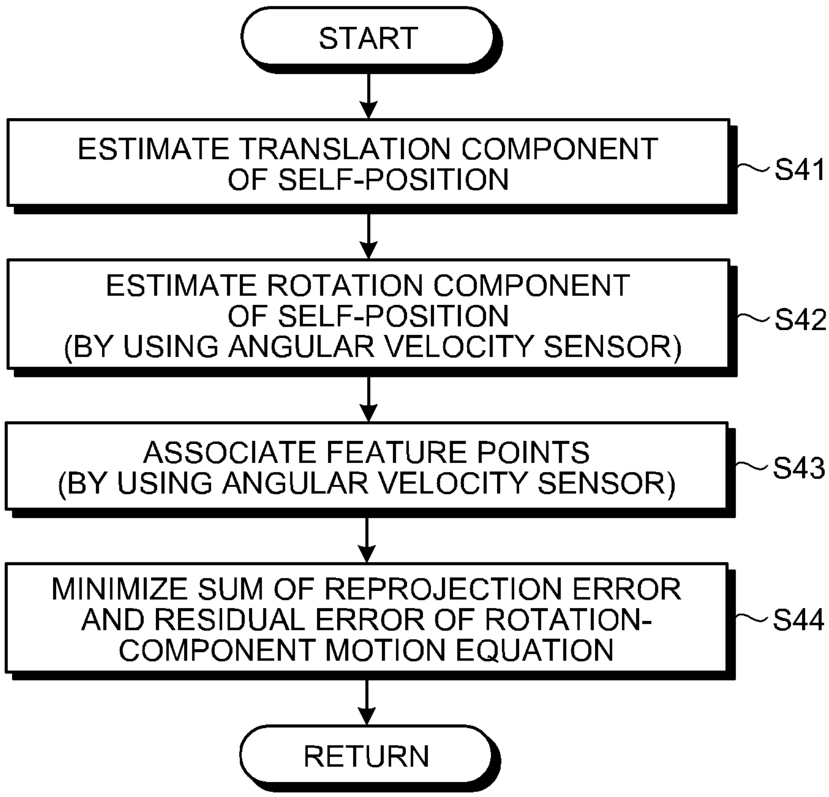

START
ESTIMATE TRANSLATION COMPONENT OF SELF-POSITION
S41
ESTIMATE ROTATION COMPONENT OF SELF-POSITION (BY USING ANGULAR VELOCITY SENSOR)
S42
ASSOCIATE FEATURE POINTS (BY USING ANGULAR VELOCITY SENSOR)
S43
MINIMIZE SUM OF REPROJECTION ERROR AND RESIDUAL ERROR OF ROTATION-COMPONENT MOTION EQUATION
S44
RETURN

FIG.8

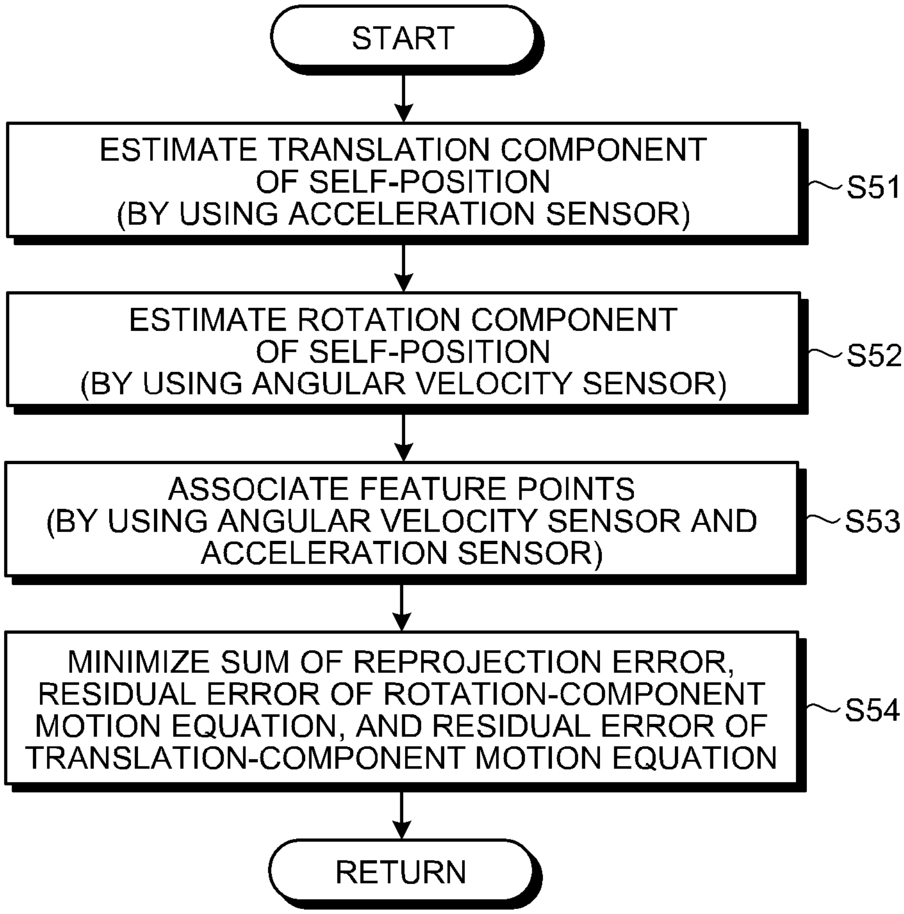
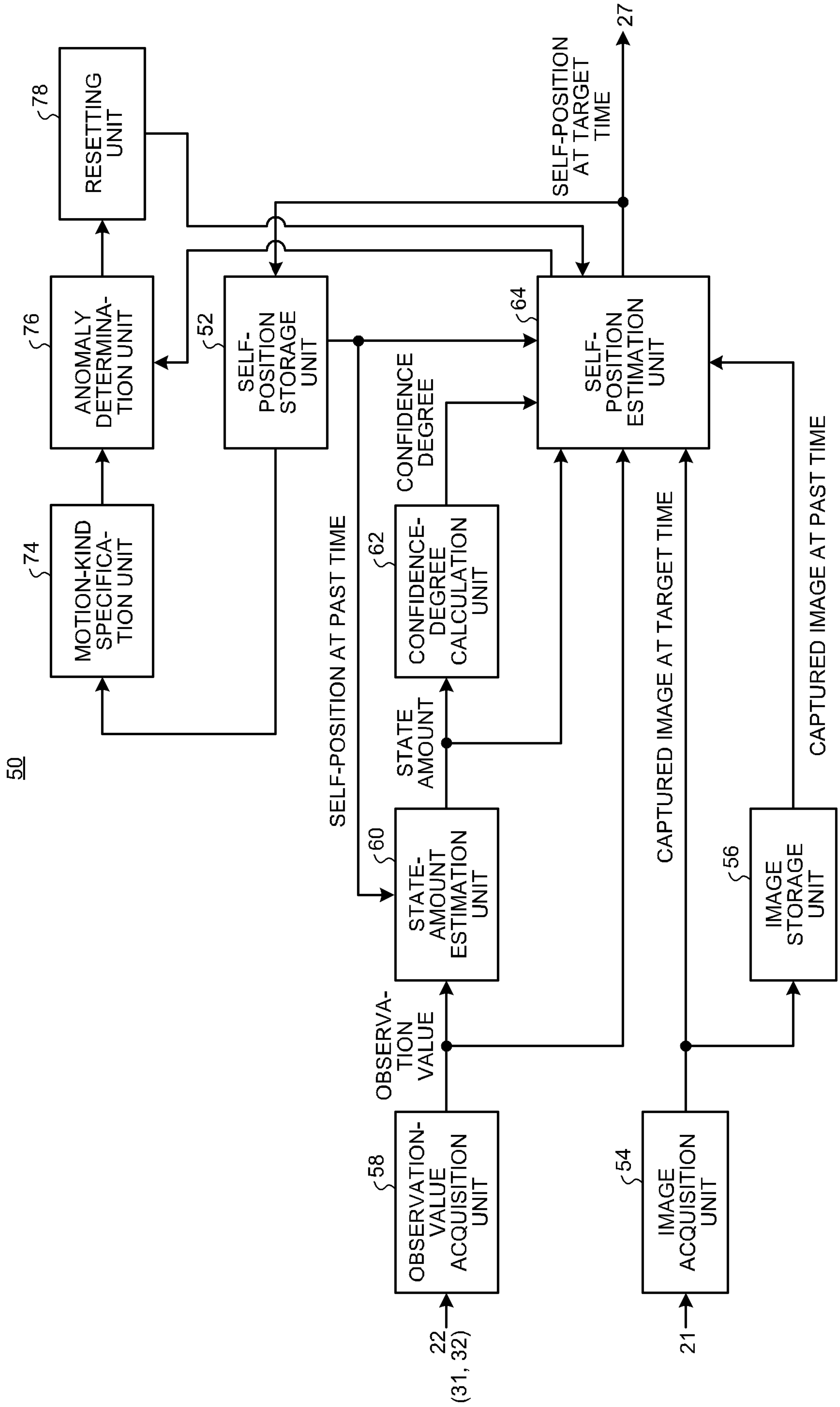

START
ESTIMATE TRANSLATION COMPONENT OF SELF-POSITION (BY USING ACCELERATION SENSOR)
S51
ESTIMATE ROTATION COMPONENT OF SELF-POSITION (BY USING ANGULAR VELOCITY SENSOR)
S52
ASSOCIATE FEATURE POINTS (BY USING ANGULAR VELOCITY SENSOR AND ACCELERATION SENSOR)
S53
MINIMIZE SUM OF REPROJECTION ERROR, RESIDUAL ERROR OF ROTATION-COMPONENT MOTION EQUATION, AND RESIDUAL ERROR OF TRANSLATION-COMPONENT MOTION EQUATION
S54
RETURN

FIG.9


50
MOTION-KIND SPECIFICATION UNIT
74
ANOMALY DETERMINATION UNIT
76
RESETTING UNIT
78
SELF-POSITION STORAGE UNIT
52
SELF-POSITION ESTIMATION UNIT
64
SELF-POSITION AT TARGET TIME
27
SELF-POSITION AT PAST TIME
CONFIDENCE DEGREE
CONFIDENCE-DEGREE CALCULATION UNIT
62
STATE AMOUNT
STATE-AMOUNT ESTIMATION UNIT
60
OBSERVATION VALUE
OBSERVATION-VALUE ACQUISITION UNIT
58
22 (31, 32)
CAPTURED IMAGE AT TARGET TIME
CAPTURED IMAGE AT PAST TIME
IMAGE STORAGE UNIT
56
IMAGE ACQUISITION UNIT
54
21

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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